Vol. VI. FEBRUARY, 1890. No. 10.

American Meteorological Journal.

A Monthly Review of Meteorology and Medical Climatology.

TABLE OF CONTENTS.

ORIGINAL ARTICLES: PAGE

On Globular Lightning. DR. T C. MENDENHALL, Superintendent U. S. Coast and Geodetic Survey 437
Royal Meteorological Society 447
Ferrel's Convectional Theory of Tornadoes. WILLIAM MORRIS DAVIS and CHARLES EMERSON CURRY. (Concluded.) 448
Diminution of Temperature with Height. PROFESSOR H. A. HAZEN 463
Effects of Sea Air on Tuberculous Affections. DR. HAMEAU 466
The International Meteorological Congress at Paris. A. LAWRENCE ROTCH 473
Rainfall in Michigan—February. N. B. CONGER, Director of State Weather Service 485

CORRESPONDENCE:

Public Meteorological Stations. O. B. C 489
Coincidence of Extreme Weather about the Northern Hemisphere. M. A. VEEDER, M. D. 489
Anemometer Experiments. C. F. MARVIN 490
Poudré. LUDOVIC ESTES 491

CURRENT NOTES:

The Batavia Observatory 492
Signal Service Bibliography 492

ANN ARBOR, MICH., U. S. A.:
METEOROLOGICAL JOURNAL COMPANY.
19, 21 and 23 Huron Street.

Single Copies, 25 cents. Per Annum, $2.00. In European Countries, $2.25.

Entered at the Ann Arbor Postoffice as Second Class Matter.

METEOROLOGICAL TABLES.

BY

H. A. HAZEN,

ASSISTANT PROFESSOR SIGNAL OFFICE.

This Handbook contains forty-seven tables, all that are needed by the working meteorologist. It includes tables for Fahrenheit and Centigrade conversions, for barometric hypsometry and reduction to sea level, for the psychrometer, for wind reductions, for conversion of English and French measures, and a collection of miscellaneous tables of especial value in meteorological work. Tables containing monthly normals of pressure, temperature and wind direction for the United States, embodying nearly fifteen years' observations, are added, together with charts of these normals for January and July.

The form adopted for the different tables is based on their practical application in meteorological work, and will be found well suited for rapid and accurate calculation.

Professor Waldo, in *The American Meteorological Journal*, for October, 1888, says: "I heartily recommend them to all of our workers in meteorology, and do not see how any of our American meteorologists can afford to be without a copy."

Handbook of Meteorological Tables. 127 pp. 8°. Price $1.00. Will be sent postage paid, on receipt of price by the author, Box 427, Washington, D. C., or by the publishers, Kittredge & Moran, Ann Arbor, Mich.

WANTED: Back numbers of the AMERICAN METEOROLOGICAL JOURNAL. Subscribers who have any numbers of Vols. I, II, or III which they wish to dispose of will confer a favor by dropping card to the Publishers of this Journal.

TO SUBSCRIBERS.

HAVE YOUR

METEOROLOGICAL JOURNALS

NEATLY BOUND.

The Register Publishing Company,

OF ANN ARBOR, MICH.,

Printers of THE METEOROLOGICAL JOURNAL, wishes to state that all subscribers to THE JOURNAL can have their Journals bound at the following low rates:

Full Cloth per vol., 12 Numbers,	**$0 80**
Leather Back and Corners, per vol., 12 Numbers,	**1 00**
Full Library " " " "	**1 00**
Half Morocco " " " "	**1 35**

It will pay you to have your Journals bound up in this way and thus preserve them in a permanent and convenient form. Unless near Ann Arbor, mail the Journals to us and we will mail the bound volumes to you. Missing numbers supplied. Give us a trial order. We are sure we can please you.

REGISTER PUBLISHING CO.,
ANN ARBOR, MICH.

THE AMERICAN
METEOROLOGICAL JOURNAL.

VOL. VI. ANN ARBOR, FEBRUARY, 1890. No. 10.

ORIGINAL ARTICLES.

ON GLOBULAR LIGHTNING.

BY DR. T. C. MENDENHALL,
Superintendent U. S. Coast and Geodetic Survey.

Those displays of atmospheric electricity which are included under the general term "lightning" are generally remarkable for the extremely short time necessary for a single flash or discharge. This peculiarity was recognized long before the real nature of lightning was suspected, and it is easily illustrated by the appearance of a rapidly moving body when illuminated by a single flash or a succession of flashes.

But there is a phenomenon, whose existence can hardly be doubted, which has almost universally been attributed to the electricity of the atmosphere, in which this generally recognized characteristic of lightning is absent.

It is what is popularly known as globular or ball lightning.

Arago suggested the well known division of varieties of lightning into three classes: First, the zig-zag, usually presenting the appearance of narrow, well-defined threads or lines of light, the commonest and best known form; second, what is commonly called sheet-lightning, in which the illumination is diffused over large areas, often unaccompanied by thunder, and

the origin of which has been the subject of considerable discussion; third, a phenomenon much rarer than either of the others, generally known as globular or ball lightning.

The principal characteristics of the last are that it presents the appearance of a luminous sphere or globe of fire, that it generally possesses a slow motion but is sometimes at rest for a considerable time, and that its dimensions are not large, being generally described as a few inches or a foot in diameter and even in the most exaggerated accounts not over a yard; and that it is often colored, a greenish tinge being very common, and sometimes surrounded by a smoky envelope. It is in its motion that it differs most essentially from the commonly recognized forms of electric discharge. The ball of fire is often described as moving with much deliberation from point to point, now resting and now bounding from one object to another, and often remaining visible for five or six minutes, its existence terminating in a violent explosion accompanied by more or less damage to surrounding objects.

So rare is the phenomenon that few persons whose observations would be absolutely trustworthy have ever had the good fortune to meet with it, and great doubt has always existed in the minds of electricians as to its reality. Numerous attempts have been made to produce similar discharges by the use of electrical apparatus but with indifferent success, so that it is probably true that skepticism as to its existence has rather increased than diminished. It has become common to explain occasional descriptions of its occurrence by attributing it to optical illusions, largely due to the abnormal condition of the observer at the time of its supposed appearance. While this explanation is doubtless sufficient to account for some reported instances, it seems certain that to others it will not apply.

Arago records eighteen instances of the occurrence of globular lightning, and after reviewing these Dr. Lardner remarks that "before the concurrent force of this evidence all doubt as to its reality must disappear." Nearly all of the instances related by Arago occurred in the eighteenth century. Others were recorded before that date and many since, in fact there is

said to be a list of a hundred and fifty authentic instances extant, collected by a Dr. Sestier.

It may be useful to give brief accounts of some of the earlier published reports, not included in Arago's list, as exhibiting the nature of the phenomenon and illustrating the character of the reports made concerning it. These have been mostly drawn from the Transactions of the Royal Society and are given preference to others on account of the probable greater reliability of testimony admitted to the published proceedings of that body.

The earliest case recorded is that of a church in Stralsund in Pomerania, in which on Sunday, June 29, 1670, lightning came down through a large hole in the upper vault of the lesser steeple, falling in the shape of a "black fiery ball," directly upon the altar. Much damage was done and the church was full of people.

On July 24, 1681, on the ship *Albemarle*, something was observed to fall on the stern of the vessel, breaking to many small parts and doing much damage. It was described as bituminous matter, smelling much like fired gunpowder. This is clearly not a good case of ball lightning.

The officers of the ship *Coronation* reported that on October 23, 1685, "a great ball of fire came into the gun room ports, throwing a boy out of one of them, by which he was drowned;" also, several workmen were made senseless and the fire ball ran up and struck a sideboard, after which it played about the room, finally breaking up into many small balls, some of these about the size of a musket bullet. This is a good example.

As a curious description of a still more curious phenomenon, the following account by the Rev. A. Vievar is given in nearly the words of the original:

On Sunday the 12th of March, 1731 or 1732 (the exact year seems to be uncertain) while walking in his garden between one and two o'clock in the afternoon he heard as it were a loud clap of thunder from the northeast. While looking into the air the noise was repeated very loud, but seemed more like the violent fall of a house, so that he expected every moment an outcry from the town; but he was soon undeceived when it began

again, and he found it made towards him, with a different noise from the former, being like the grinding of flint stones, but very loud. The object seemed to be about three feet wide. He found it sink in the air and as it seemed to point directly at his head, he laid himself down on a grass slope to let it pass over. However, at the upper end of the walk it fell to the ground and came rolling down the grass walk and he can compare it to nothing better than to that of a violent grinding of flint stones, or a coach and six at full speed on a causeway of loose stones. He lay attentive, expecting to see something, and saw a piece of wood come running before it. When the phenomenon came to the water side it twisted up a large stake that stood in its way and tossed it towards him with much violence, and immediately fell into the water, with the violence and noise of a red-hot mill-stone.

He had seen the seas break against a rock in a storm but never saw a greater ferment caused by the boiling of the waters. It staid about a quarter of a minute in the water, and then mounted again into the air, and went rattling away but with much less violence. He heard it for about a quarter of a mile and lost it. It came against the wind and not faster than a man may walk. The froth and foam of the water remained thirty hours afterwards.

On November 4, 1749, the captain of the ship *Lizard* was taking observations, when he was asked by an under officer to look to the windward which he did and observed a large ball of blue fire rolling on the surface of the water at about three miles distance. It came on them very fast and rising out of the water at the ship's side "it went off with an explosion as if hundreds of cannon had been fired at once." The ship was filled with a sulphurous smell and the masts were much injured; several men were injured by the shock. The ball appeared to be as large as a mill-stone when it struck the ship.

This is an important although an extraordinary case, the phenomenon having been seen by two witnesses, one of whom called the attention of the other to it, and it would seem to be impossible to attribute it to any form of subjective disturbance.

On July 16, 1750, the house of Mr. Horsfield, at Dorken in Surrey, was struck by a powerful discharge of lightning, accompanied by a terrific peal of thunder. Several persons saw large balls of fire which, as they fell on the houses or ground, divided into innumerable parts.

This is not an uncommon appearance incident to an ordinary lightning discharge of somewhat unusual violence.

Very similar in nature was the "globe of blue fire as large as his fist" which was seen by the engraver Sokolow, to pass from his insulated rod to the forehead of the lamented Professor Richman, on August 6, 1753.

It will be admitted that the foregoing evidence, and it fairly represents much of what was relied upon by Arago and others who studied the question in the early part of this century, is not as convincing as could be desired to establish the existence of an electrical phenomenon so contrary in its character to that of any of the ordinary forms of electrical discharge. Most of these observations were made at a time when the nature of lightning was not known and when the spirit of exact observation and inquiry was less prevalent than at present. Many of these accounts are unquestionably gross exaggerations, and some of them undoubtedly refer to phenomena which were not electrical in their character. But even when sifted as thoroughly as possible, there will remain among them, and in the collections of Arago and others, some careful descriptions of unquestioned authenticity, leaving little room for doubt that what was described was actually seen.

Many of the instances in which globular lightning was observed are recorded as having occurred at sea. For records of a number of cases in which it has been there very recently observed, I am indebted to Lieut. G. L. Dyer, Hydrographer of the U. S. Navy, who has kindly abstracted these from the reports received at the Hydrographic office, and placed them at my disposal for examination. Many of them refer more especially to the well known St. Elmo's fire, but some are good descriptions of "ball lightning," and as most if not all of them refer to observations made during the past two or three

years it will be important to present their essential features.

The British bark *Lillian B. Jones* encountered a severe electric storm on the 22d of March, 1887, during a heavy gale. There was much thunder and lightning, St. Elmo's fire at all points; sea full of phosphorescence; compasses and barometer very much affected, and numbers of *fire balls* were observed flying in the air.

The brig *Hyperion* uses almost exactly the same language in describing an electric storm encountered on the 7th of March, 1887.

The British brig *Edward B.* reports a severe electric storm on the 14th of March, 1887; sea full of phosphorescence and numerous *fire balls* flying in the air.

The bark *John H. Pierson* reports that during a hurricane on August 25, 1886, between 9 and 11 P. M., and while the rain was falling heavily numerous *balls of fire* were seen to shoot up from the northern horizon reaching an elevation of at least 30° and covering a horizontal angle of at least 20°. This is a curious and unusual phenomenon; another instance is related further on. It would be important to know whether it was observed by any other vessels that might have been in the vicinity.

Steamship *Bulgarian*, on November 29, 1888, encountered a heavy thunder-storm with sheet-lightning and St. Elmo's fire. At 10 P. M. a *ball of fire* fell; it was of a pale blue color and just before disappearing it threw off another ball behind it of a yellowish tinge.

From this brief description it is by no means certain that the phenomenon was electrical.

On the night of November 12, 1887, the British steamer *Siberian* encountered a "fire ball," which is thus described by Capt. Moore: At midnight, while off Cape Race, a large ball of fire appeared to rise out of the sea to the height of about fifty feet and come right against the wind close up to the ship. It then altered its course and ran along the ship to a distance of about one and one-half miles. In about two minutes it again altered its course and went away to the southeast against the wind. It

lasted in all not over five minutes. The Captain adds that he has "seen such a phenomenon before in about the same locality. It seems to indicate the coming of an easterly or southeasterly gale."

This ball of fire is sufficiently orthodox in its appearance and behavior to satisfy the most exacting, and it is extremely gratifying to know that in addition to its other excellent traits it possesses the rare power of storm prediction.

Capt. Grace, of the schooner *Rebecca Smith*, on August 10, 1888, during squally weather with thunder and lightning and heavy rain, observed a bolt of lightning in the shape of a ball fall in a perpendicular (zig-zag) line from the zenith and strike the surface of the water less than a length from the vessel's beam. There was apparently no disturbance of the surface when the lightning struck (although this might have been missed in the glare of the lightning), but for the space of at least five minutes after the lightning struck, a thin blue smoke, similar in appearance to powder smoke, was seen to rise from the surface to a height of at least ten feet. The smoking surface was generally circular in form, about twelve or fourteen feet in diameter, and had the spot in which the ball struck for a center. The occurrence took place in broad daylight.

Bark *Hannah McLoon* reports a severe electric storm on February 27, 1887. All points and all wire rigging brilliantly illuminated; *fire balls* flying in the air.

Captain Mitchell, of the English steamer *Montmore*, reports that on January 28, 1885, "*a ball of St. Elmo's fire* fell between the bridge and foremast and afterwards played upon the foremast and gaff." This ball of fire was so bright that for a time it blinded the officer on watch.

British brig *Nellie Crosby* reports terrific thunder and lightning on November 30, 1886. A *ball* burst between the masts, completely blinding all on board. Sea full of phosphorescence.

The British steamer *Siberian* reports that on January 17, 1887, a brilliant display of St. Elmo's fire was observed, taking the shape of *balls of fire* shooting up from the horizon all around the vessel and bursting at an altitude of about 5°; one

ball showing a green light was mistaken for a vessel's side light.

The bark *Abram Young*, on April 6, 1889, encountered a severe storm, during which a ball of fire ran down the starboard main royal backstays and burst with a report like a gun about six feet above the deck.

The steamer *Carthaginian* reports a peculiar flash of lightning on November 20, 1888, which resembled two *blue balls of fire*, passing directly over the ship and accompanied by a very loud peal of thunder resembling the firing of rifles or artillery.

The schooner *Harry White* encountered a hurricane on April 7, 1889. A thunder storm "began at 1 P. M., and at 3 P. M. a large *ball of fire* struck the foremast head, scattering in various directions and completely blinding every one on deck for several minutes. The entire ball dropped into the water close by the ship." This record is certainly defective in not explaining how the scattered fragments were gathered together before dropping into the water.

To the above, from the records of the Hydrographic Office, may be added one or two newspaper notices of a recent date.

The steamer *Alene* of the Atlas line was struck by a heavy gale accompanied by thunder and lightning on July 20, 1889. About noon the man on the lookout "saw an immense *ball of fire* fall from the heavens; the ball struck the main-top, glided down the rigging and danced around the deck. Before the lookout's eyes had recovered from the flash of light there was a fearful clap of thunder and the ship rocked as if she had struck something solid." Only slight damage was done to the mast.

The Macon (Ga.) *Telegraph* describes an electric storm occurring near Atlanta as follows:

"On Sunday afternoon the people of East Point, a village six miles from Atlanta, were shocked from a stroke of lightning the like of which had never been experienced by any of them before. About dusk a gray cloud hung over the town. There had been no lightning, no thunder, nor any indication of an electric storm. Suddenly a flash and a crash came simultane-

ously and people rushed from their houses with blanched faces. The danger was passed but the experience was terrible. There had been an electric shower. The lightning had separated into twenty or more bolts and struck as many places within a radius of a quarter of a mile. The air was filled with the odor of brimstone, and a copper-colored cloud floated northward from the city. A wind-mill was struck and damaged, the grass on a lawn was burned up, a window in a house was shattered and the carpet in a bedroom scorched, a cow was killed, a tree split open, and a telegraph operator knocked from his chair. The most wonderful thing about the electric shower was the rolling of great *balls of fire* up the railroad tracks. The small masses went bouncing and cracking along the rails to the terror of the citizens."

I am indebted to Mr. B. A. Colonna, Assistant in charge of the office, U. S. Coast and Geodetic Survey, for a very detailed and satisfactory description of an observation of ball-lightning made by him on the 23d of May, 1855. In company with several others he was fishing in the Chesapeake bay and was driven to land at a wharf near the mouth of a small creek by the sudden appearance of threatening weather. On this wharf were several piles of old ships' cables or similar chains used for anchoring buoys. It was about 1 A. M. when the wharf was reached; the rain was falling in torrents and it was very dark. Suddenly there was a deafening crash of thunder accompanied by the most vivid lightning. As soon as the first brightness had disappeared, it was observed that the surroundings were still illuminated by numerous *balls of fire* which rolled quietly along the wharf towards and over the cables. They seemed to increase in size from a small spark up to a diameter of four to six inches. Sometimes two would join and disappear with a slight sound, others fade away. The display did not last more than a minute and possibly its duration was much less than that. All of the party, consisting of four or five persons, observed the phenomenon, agreeing in their description of it except as to the apparent size of the fire balls. No one was in the least injured or even shocked by the electrical discharge, and

an examination the next morning failed to show any traces of it on or about the wharf.

An interesting and important case is reported recently by Mr. Walter G. McMillan, of Calcutta. On Saturday, the 8th of June last, a house in the suburbs of the city, belonging to Mr. Viney, was struck by lightning. Among other less rare exhibitions incident to the stroke was a "ball of lightning" which was directly seen and watched by Mr. Viney, who describes it as appearing like "an intensely brilliant ball of yellow fire, about six or seven inches in diameter, which passed from one end of the room to the other at a pace just sufficiently slow to allow it to be readily followed by the eye. About halfway across it appeared to be momentarily checked, and then, seeming to burst with a deafening report which shook the house, it scattered and passed away." He states that he is absolutely certain that there was no premonitory warning, no sound of brush discharge or odor of ozone, the first intimation being the entrance of the fire ball itself. He also adds that the whole house seemed to be filled with an orange-colored gas, the breathing of which was perfectly stifling and was equivalent to inhaling the fumes from burning sulphur.

Much additional information concerning globular lightning could be obtained, especially if the columns of the daily press were drawn upon.

The principal object in view has been, as already indicated, to exhibit the character of the phenomenon and the nature of the evidence attesting its reality. While the latter certainly leaves much to be desired, it will generally be admitted that, with Dr. Lardner, we will hardly be able to entertain doubts as to its reality in the face of such extensive, although not always concordant testimony.

But if the reality of "ball lightning" be admitted, we are confronted with the problem of its nature and origin, which offers many difficulties and which calls for more extensive and more careful observations of its appearance and behavior.

In this connection it may be suggested that future accounts, to be useful, should be more explicit in reference to the motion

of the "fire ball," whether fast or slow, and what directions, between what objects, etc.; how long it is visible, whether seen by one or many, and especially whether it is independently noted by several and to what extent their accounts, when prepared or given without interchange of experience, agree as to the number, size, shape and color of the "fire balls," and as to other particulars.

Better than almost anything else as an unimpeachable witness would be a photograph of a ball of lightning, and now that the camera has become well nigh omnipresent, it is to be hoped that the testimony of the dry plate may soon be available.

ROYAL METEOROLOGICAL SOCIETY.

The first meeting of this Society for the present session was held on Wednesday evening, November 20th, at the Institute of Civil Engineers. The following are among the papers read:

(1) "Second Report of the Thunder-storm Committee." This is a discussion by Mr. Marriott on the distribution of days of thunder-storms over England and Wales during the seventeen years, 1871 to 1887. Notices of sheet lightning are included in the term "thunder-storms." The years of greatest frequency were 1880, 1882, 1884, and 1872; and the years of least frequency 1887, 1874, 1879, and 1871. Years of greater or less frequency alternate regularly throughout nearly the whole of the period. The average yearly number of thunder-storms is about thirty-nine. The districts with the greatest yearly frequency are the south of England and extreme northern counties; and those with the least yearly frequency are Cheshire, Lancashire, and Yorkshire. The greatest number of thunder-storms occur in July, and the least in February and December.

(2) "Notes on Cirrus Formation," by Mr. H. Helm Clayton. The author, who has made a special study of cloud forms and their changes, gives a number of notes and drawings on the formation of cirrus under various conditions. Curved cirrus clouds accompanied by decreasing barometric pressure often indicate that a storm of increasing energy is approaching.

FERREL'S CONVECTIONAL THEORY OF TORNADOES.

By William Morris Davis and Charles Emerson Curry.

(CONCLUDED.)

12. *Development of Tornadoes in Cyclonic Areas.*—If the reader accept the conclusion now stated as to the dependence of tornadoes on a state of instability in the atmosphere, and as to the characteristic occurrence of this state in the southeastern quadrant of certain cyclones, he may still inquire into the manner in which the special peculiarities of tornado motion arise. In stating this, we shall still follow the lead of Ferrel's writings.

If over-warm and moist lower air escape upwards in a comparatively small updraft, the lower indraft will take on a distinct rotation, as is easily seen in the desert whirls. When the whirl springs up from a state of calm, and its supply is drawn from a moderate area, the rotation is indifferently one way or the other, according to the manner in which the several parts of the inflow meet. But if the inflow be drawn from a mass of air, which itself is moving around a central point, then the whirl must rotate in the same direction as the mass in which it is formed. Tornado whirls are formed in air masses which make part of cyclonic storms and partake of their rotation; hence tornadoes should rotate as cyclones do, from right to left (in this hemisphere); and this is the case, the exceptions being rare and doubtful. It is interesting, however, to note that, when Ferrel stated that tornadoes arise in calm air, he went further and said that they turn in either way; it was only after perceiving their relation to cyclones that their constant direction of rotation was indicated.

The violence of tornadoes indicates a strong updraft where the convectional ascent takes place. To create a strong updraft, we must have a hot fire and a high chimney; hence tornadoes need be expected only when the instability is excessive, allowing the lower air to ascend to a great height before reaching a stratum of its own density. An ordinary cyclonic storm may induce only sufficient instability in its southern part to

produce the high clouds that abound there; when the contrasts of temperature are stronger, the clouds may grow to the size of thunder-storms, which are much commoner than tornadoes, although like them chiefly produced (in our country) in the southern part of cyclones; but it is only when the instability is excessive that tornadoes are developed. We have few well determined facts that serve to define the beginning of the operation with any sharpness. It is known that tornado whirls make their way down to the ground from aloft; that tornadoes are associated with thunder-storms and occur within them; and that they are local and short-lived compared to thunder-storms. We naturally infer from this that tornadoes are the product of a higher development of the instability that causes thunder-storms as a whole, but the precise relations of the two are hidden in heavy clouds. Here we must "theorize" again, and measure our success by our ability to account for all the phenomena of tornadoes. Seeing that thunder-clouds have many "heads," and recognizing in every one of these a somewhat independent updraft, we may suppose that the more energetic currents, drawing their supply quickly and from a large area beneath, develop tornado whirls, while the weaker ones, if whirling at all, do not propagate the disturbance down to the ground. But it must be clearly understood that the violent tornado blast that is felt at the surface of the earth is not the direct movement of the air in its convectional ascent. No admissable assumption concerning contrasts of temperature could generate an updraft of such intensity as a destructive tornado wind. It is the same with cyclones. The violence of their wind is not the immediate product of the convectional overturning on which they depend; if it were, they would occur on the equator, where they are unknown; their violence is a consequence of their rotary movement. Cyclones take on a faint rotary movement, because their would-be radial indrafts occur on a rotating sphere, and in a latitude where the deflecting force arising from the rotation of the sphere suffices to change the radial indrafts into spiral indrafts. The rotary movement thus initiated is increased as the winds approach the center of rotation in accordance with a well-known mechanical

law, the "conservation of areas," which embodies the principle that as a given mass of air is drawn toward the center, the radial line joining it with the center must sweep over "equal areas in equal times." A wind of moderate rotary velocity at a great distance from the storm center thus becomes a hurricane when the center is closely approached. The surface winds, being more impeded by friction than those half a mile above the earth, especially on land, do not acquire so great a whirling velocity as those above them, and hence incline more to the left towards the center, as may easily be seen by comparing the direction of the surface winds and of the lower clouds during one of our ordinary cyclonic storms.

The same principles apply in the explanation of tornadoes. An indraft is established in the lower air in consequence of an updraft, and the indraft takes on a rotation in consequence of its establishment within a cyclonic storm, as has been stated. As the gently rotating indraft approaches the central axis of the updraft, its rotation increases, even to the velocity of a hundred or more miles an hour; and near the funnel cloud, its whirl must be almost circular. Curiously enough, the whirling of the air prolongs the life of the tornado, for the centrifugal force of the whirl retards the indraft. Illustration of this may be made by comparing the time required for a basin to empty itself by a vent at the bottom, first opening the vent while the water is quiet, and then repeating the experiment after setting the water in gentle rotation.

It must not be imagined that there is any undue special pleading in this explanation. The processes described are in reality extremely simple, and the mechanical laws quoted to account for them are beyond question. The agreement of the direction of rotation between tornadoes and their parent cyclones is of the same kind as the agreement between cyclonic rotation and the rotation of the earth; or as between the rotation of the planets, including the earth, and their motion in their orbits. The increase in the rotary velocity of tornado and cyclonic winds is an effect of the same kind as that seen in the increase of the earth's orbital velocity as it approaches the sun, in passing

from aphelion to perihelion; or as the increase in the velocity of the whirl in a water eddy near its center. Given the fact of ascensional currents, such as the tornado and its clouds present us, and there must be an inflow of air at the bottom of the current; given the inflow towards any point in a cyclonic wind, and it must assume a whirl in the same direction as that of the cyclone; given the beginning of a whirl, and its velocity must increase as its winds run toward the center. This is all an entirely legitimate deduction from the premises of the problem, in accordance with well tested physical and mechanical laws: and as the deduction accords with facts of observation, we are warranted in thinking that the solution of the problem is correct.

13. *Low Pressure at the Center of Tornadoes.*—The high rotary velocity near the axis of the updraft requires, however, that there should be no significant retardation of the whirl by friction, and hence we cannot suppose that excessive rotary velocities will be thus produced close to the ground. But the centrifugal force of the rapid rotations at a moderate height above the ground holds the air away from the axis of the whirl, and produces a distinct reduction of pressure there, and it is inrush of surface air to this low pressure core of the tornado that is felt as a destructive blast on the ground. It should not be inferred that there is any arbitrary plane of separation between the surface air that is largely controlled by friction and the higher air that is not; there is simply the gradual introduction of control by friction toward the ground, so that the lower air, which fails for this reason to attain a great whirl and a great centrifugal force, is drawn into the low pressure core produced by the strong centrifugal force of the rapid whirl above. The same thing is seen in large cyclones, where the rapid movement of the higher currents produces an arrangement of pressures that in part determines the movement of the surface winds; for the low pressure at the center of a cyclone is in good part the effect of the centrifugal forces of the whirl, and the surface winds with moderate velocity and correspondingly more moderate centrifugal force are drawn towards the low pressure cen-

ter that the higher winds produce. Here again, therefore, Ferrel's explanation does not demand arbitrary or unexampled processes; it accounts for the violence of tornadoes on perfectly rational principles that find accepted application elsewhere as well.

It should however be understood that the low pressure at the center of a tornado is a deductive conclusion, not an observed fact; but the more carefully the deduction is followed, the more confidence one must gain in its correctness; and moreover there are certain phenomena of tornado action that seems to bear it out. House walls are sometimes blown outward and corks are blown from bottles; both these effects being generally and we believe correctly ascribed to the relief of pressure on the outside of the house or bottle.

Objection to the occurrence of low pressure in the core of a tornado whirl is made by Hazen,* who indeed is disposed to cast doubt on all aspects of the theory. He urges that as the pressure is well known to increase under thunder-storms, and as tornadoes are regarded as a high development of thunder-storms, the pressure below them must be still more increased and not diminished at all. The objection does not seem to be well founded, for it fails to take account of the causes of increased pressure in thunder-storms and of the decreased pressure in tornadoes. It would be as reasonable to question the occurrence of higher pressure in thunder-storms, because the cyclonic troughs in which they are commonly generated are of low pressure. The slightly increased pressure under thunder-storms and the accompanying outburst of the squall-wind, have been variously referred to the heavy downfall of the rain, but the out-blowing wind is said to have been observed in storms without rain; or to the cooling of the air in the shadow of the cloud, but it occurs at night as well as by day; or better still to the reaction of the rapid expansion of the great updraft, this being again one of Ferrel's recent ingenious suggestions. The amount of increase is small, hardly more than five or eight-hundredths of a barometric inch, and it appears

* Amer. Met. Jour., iv, 171, 313.

simply as a slight rise in the general down-curve or trough of pressure caused by the controlling cyclone. If at the same time some other cause is set in action, whose effect would be locally to diminish the atmospheric pressure, the barometer will simply measure the total resultant pressure; and the winds will obey the same resultant. A violent whirl is certainly such a cause, and is entirely sufficient to reduce the pressure at its center much more than the downward reaction of the expanding air in the thunder-storm can increase it. It is therefore entirely reasonable to adhere to the generally accepted theory of the low pressure in the center of a tornado, and to ascribe the bursting outward of buildings and other related phenomena at least in part if not wholly to its action. It is not likely that we shall soon have instrumental record of an effect that is limited close to the dangerous center of a tornado, and the measure of credence that we give to it must depend chiefly on our understanding of the physical processes concerned. It may be worth while to note that two examples of tornadoes which Hazen* quotes quotes from Ferrel† as showing the rise of the rise of pressure by direct observation in storms of this class, are not tornadoes at all, but are thunder-squalls, or what Hinrichs has called "derechos,"‡ as is easily perceived from the accounts of their action. There is no mention of a whirling wind, but only of a squall. A third example of a tornado in Indiana in 1852 is given, but the context of Chapplesmith's original account§ makes it clear that the storm there described was a tornado in a thunder-storm, just as the thunder-storm was in a cyclone. The place of observation was five miles north of the tornado track, and quite out of reach of the effects of the tornado whirl. The curve of barometric pressure given by Chapplesmith is essentially identical with curves that may be obtained from cyclonic thunder-storms any summer season, and gives no evidence whatever of the pressure curve for a tornado. Now that the distinction between cyclones, thunder-storms and

*Amer. Met. Journ., iv, 314.
†Meteorological Researches, pt. II, 94.
‡Amer. Met. Journ., v, 307.
§Amer Journ Science, xxii, 1857, 18. Smithson. Contribs., vii, No. 59.

tornadoes is well understood, there is no need of confusion in such a question as this.

14. *Tornadoes Begin in the Cloud Layer.*—Let us now return to the consideration of the atmospheric instability generated in the southeastern quadrant of a cyclone, and of the consequent establishment of a tornado. The diagramatic method may be again employed, figure 6 with the addition of approximate quantitative accuracy to the adiabatic lines, taken from the essay by Hertz, already referred to, in which the physical changes of temperature of ascending currents are represented in a form so highly instructive and convenient to meteorologists. The scales in this figure are for centigrade degrees and meters. Let CD represent the normal average rate of vertical decrease of temperature in the atmosphere in the tornado season and region. When the cyclonic winds are well established, the temperature will be raised in the stratum of southerly winds and lowered in the overlying stratum of westerly winds; while at a still greater height, above the limit of active cyclonic circulation, there is little change from the normal. CD thus becomes EFGH; and in the afternoon, under the influence of strong sunshine, a general increase of temper-

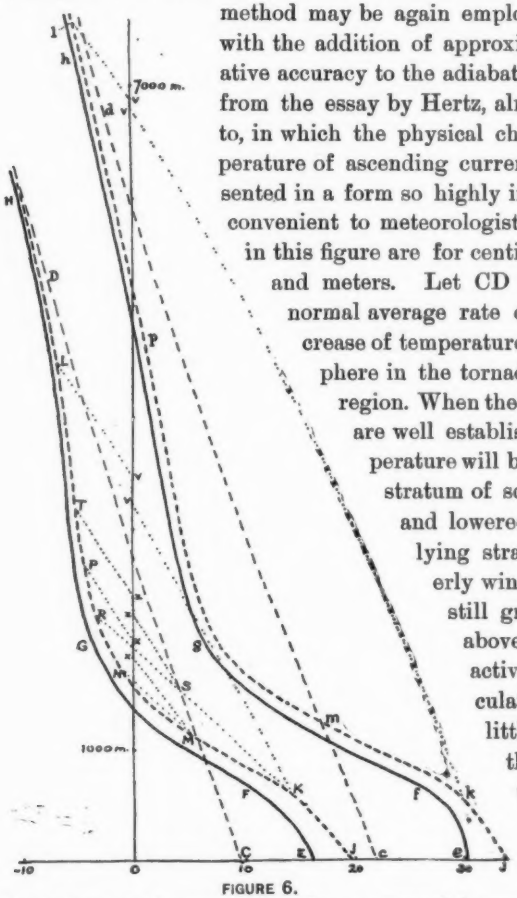


FIGURE 6.

ature takes place, of greatest amount near the ground, so that EFGH becomes JKL. The air is now primed for the formation of a tornado. If any overturning take place, it will be most likely to begin where the instability is strongest; that is where the curve JKL has the least slope, as at M, where the most rapid vertical change of temperature takes place. This is generally in the cloud stratum where the air is saturated, and hence as convectional ascent begins, the adiabatic decrease of temperature is retarded by the evolution of latent heat, as shown by MxxP.* Equilibrium is not gained until the warm lower air has risen from M nearly to P; its failure to reach its full theoretic height being due to cooling by mixture with and conduction to the surrounding cooler air. Warmer air from a less height, such as K, follows the first ascending current, and must needs rise to a greater height, and thereby a sufficient violence of updraft may be developed to cause an active tornado, which includes lower and lower air in its whirl as it is better and better established, until it reaches the ground. Thus we find reason for the first appearance of tornadoes at a considerable height above the ground, in contrast to the beginning of desert whirls which are first seen at the ground, where the instability of the air concerned in their formation is strongest, as appears in figure 1.

The diagram, figure 6, offers a convenient means of deducing the conditions most favorable for the development of tornadoes. Remembering that the intensity of the updraft, on which the whole process depends, increases with the height that it reaches and the velocity with which it ascends, we may say that tornadoes will be strongest when the two portions of the temperature curve, JK and NL are farthest separated horizontally, indicating the greatest contrasts between the under and upper winds; when K is of considerable height, indicating an ample

*The break in the line MP at xx, where the line of freezing is crossed, is due to th presence of condensed vapor in the form of minute liquid drops; there can be no cooling until all the drops are frozen; hence there is a moderate ascent, xx, during which the energy needed for expansion is supplied from the latent heat of liquefaction. See Amer. Met. Jour., iii, 493, where the explanation of this curious reaction is given, following Hertz.

supply of warm air below; when the slope of KM is flattest, indicating relatively abrupt change from the warm lower to the cool upper winds; when the lower air is of the highest relative humidity, so that the curve of adiabatic cooling, KvvL, may be as steep as possible, and its intersection, L, with the air temperature curve as high as possible; when the lower part of the curve, JK, is as far to the right as possible, for it is at high temperatures that the retardation of cooling by the evolution of latent heat in the ascending current has its greatest effect; and when the volume of ascending air is large enough not to be significantly cooled by mixture with and conduction to the surrounding cooler air, in order that the theoretic measure of altitude of L may be reached as nearly as possible. If the air at M, where ascent begins, were very dry, it could ascend only to N; and under the same unfavorable conditions, the air from K could only reach R. If the dew-point of the air from K were reached only at S, its ascent would cease at T, nearly a mile lower than if the air were saturated when its ascent began. The right hand curve, jkml, represents conditions better adapted to tornado generation than the curve, JKML. In the former, the adiabatic line of retarded cooling, kvvl, intersects the atmospheric temperature curve at nearly double the height of the corresponding intersection in the latter. The lines as drawn do not seem to represent an extreme case; for thunder-clouds have been seen to reach greater heights than 7,500 meters; and the snow that they leave on mountains and the hail that they let fall to the lower ground indicates that their upper lines when truly drawn should pass distinctly to the left of the line of freezing, in spite of their high position on the temperature scale below.

It does not now appear possible to prove the occurrence of these conditions by recorded facts; but we believe that certain observations be suggested in the sequel may in time afford means of testing some of the deductive conditions here represented.

15. *Development of the Tornado Cloud.* — Tornadoes are generally formed at the base of heavy cloud masses, part of

which may be a broad cloud stratum normally developed in the upper part of the lower cyclonic wind, by reason of its northward motion, which permits it to cool somewhat. Ferrel mentions, however, certain examples of tornado-like storms, knownas bull's eye squalls, off the west coast of Africa, where the air is hot, but dry, in which the cloud formation is insignificant.*

Our tornadoes are commonly seen to grow from small clouds below the general cloud mass, often of different tints, one light and one dark, rushing towards each other; the funnel-cloud is apparently generated where these meet, and is prolonged by a downward growth, which gives it the appearance of descent, although its parts are without doubt all the time ascending. As the strength of the whirl increases towards the ground, a whirling mass of dust and rubbish and in part perhaps of locally formed cloud, rises and joins the base of the funnel, forming the double cone or "hour-glass," that characterizes many tornadoes. The light and dark clouds, rushing toward the center of the upper whirl, probably owe their different tints to differences of density and of illumination: at least it will be well to exhaust the sufficiency of these simple causes before calling on electrification, or other remote causes. In some cases a number of observers seeing a single tornado at successive points on its track all testify to the occurrence of these light and dark clouds rushing toward the center of the whirl; and this leads us to conclude that these clouds like the funnel cloud are constantly forming in the indraft, and hence are always apparent there, although always flying to the center. The case is analogous to that of a stationary cloud on a mountain peak in a high wind; or to the front lower edge of a thunder cloud, whose fragments are all the while rushing into the cloud mass, and yet the edge of the cloud holds its place or even advances to windward. The cause of the cloud formation in the indraft may be in part due to the gradual helical ascent of the wind, expanding and cooling as it reaches a region of lower pressure, and becoming visibly cloudy as its temperature falls below the dew-point: and in other part

* Met. Researches, II. 91.

to the approach to the low-pressure center of whirl, where expansion, cooling and cloudiness are similarly produced. The stronger the whirl, the lower the pressure at the center, the greater the cooling of the indraft and the lower the level at which the cloud is formed: until in a full fledged tornado, the cloud may be produced directly at the ground. This seems to be largely the case even in waterspouts; for several examples are on record in which spouts at sea have deluged the vessels on which they broke with fresh and not with salt water. There is an old example of this that deserves quotation.

A hundred years ago, Mr. J. Perkins of Boston, discussing the problem of waterspouts, quotes an account from one Captain Welling, who said that "in a voyage from our West India islands in the month of August in a warm day just at evening, a spout fell close by the vessel, and in two or three seconds of time came across the stern, where he then was. A flood of water, as he expressed it, poured upon him and almost beat him down, so that he was obliged to lay hold of what was nearest to him, to prevent being washed overboard, which in his fright he was apprehensive of. But the spout immediately passed off with a roaring noise into the sea. I asked him if he tasted water? Taste it, said he! I could not help tasting it, it ran into my mouth, nose, eyes and ears. Was it then fresh or salt? As fresh, said he, as ever I tasted spring water in my life."*

16. *Reported Descending Currents in the Tornado Funnel.*—There is one fact sometimes reported in careful observations of waterspouts that is not accounted for by the theory as thus far stated, and that may perhaps require modification of the theory in some regards. This is an actual descent of water or cloud filaments in the interior of the ascending whirl. For example, the captain of the British steamship "Caspian," states that on October 6, 1887, in latitude 39° 32′ N, longitude 69° 10′ W, water could be seen by the use of a telescope rushing down

* Conjectures concerning wind and waterspouts, tornadoes and hurricanes. Trans. Amer. Phil. Soc., ii, 1786, 335-347.

through the center of the funnel of a waterspout and plowing up the surface of the sea to a height of 50 feet.* Again on February 15, 1888, in latitude 24° 2′ N, longitude 81° 14′ W, the captain of the American schooner "Ethel A. Merrill," reports that he saw a waterspout transparent at the base and that descending currents seemed to be plainly visible causing the water at the surface to fly in all directions.† If repeated observation prove the real existence of these descending currents within the core of the storm, as now seems likely, they promise to offer an interesting homology with the hypothetical descending currents by which Espy and Köppen have sought, and we think correctly, to account for the clear central "eye" of a cyclone. The whirl at the center of rotary storms withholds air from the axis and thus produces a low pressure center or core, into which any air, not possessed of great centrifugal force, must needs flow with great rapidity. On land, where friction with the ground prevents the attainment of a high velocity, the centrifugal force of the lower current is not sufficient to prevent it from being drawn rather rapidly toward the center, where it presumably ascends, gradually in cyclones, rapidly in tornadoes; hence the prevailing cloudiness at the center of land cyclones, and the absence of descending currents in the core of land tornadoes. But at sea, where friction is less than on land, the surface currents as well as those above attain so high a velocity that their inclination to the storm center is much less than on land; the low pressure at the center is therefore not sufficiently supplied from below and draws air down from aloft as well; hence the clear central area of violent cyclones at sea, especially of tropical cyclones, and the appearance of descent in waterspouts. But much further observation is needed to obtain direct evidence of the truth of this suggestion.

17. *Explanation of Correlated Phenomena.*—The studious reader would do well to consult Ferrel's original papers in order to see how far he has carried the quantitative determination of

* Pilot Chart N. Atlantic Ocean, December, 1887.

† Id., March 1888, Supplement. See also Nature, January 31, 1887, 333, for an excellent account of a case of this kind.

the sufficiency of his theory to explain the facts of observation. Although the mathematical treatment of the problem carries it far beyond popular exposition, there are many passages that are simple and highly instructive. Numerous examples of curious phenomena are quoted and most ingeniously accounted for. The occurrence of hail in particular is most satisfactorily explained. Cloud-bursts as well are brought into rational connection with the theory as a whole. Lack of space prevents further citation here.

18. *Features of Tornadoes still needing Observation.*—The theory of tornadoes has received little aid from observation in the past several years, chiefly because the attention of observers has not been clearly enough directed to the determination of facts concerning which there is still doubt. There is little further need of stating that tornadoes are whirling storms, that they turn from right to left, that they possess a funnel-cloud and roaring and destructive winds, that they destroy buildings and tear down trees. All this is well known. But for the satisfaction of the more skeptical, it would be well if explicit statement were still given to all indications of upward and downward motion in the whirl or funnel; and in waterspouts, careful search should be made for the reported downward currents. It is well known that an astronomer with a telescope of moderate power can see an object whose discovery needed a large telescope. So with other observations; not that an observer is to be mesmerized by a suggestion, so that he can see nothing but what is suggested; but that his opportunity for observation will be most fully utilized if he is fully aware of all previous observations and of all the discussions they have provoked. He can then discriminate critically as to facts whose very existence might otherwise pass unnoticed. In regard to the ascent or descent of the funnel; it is well known that the funnel-cloud grows longer and shorter from time to time; but it is believed that its winds and the clouds and debris that they carry are all the while whirling upward. Evidently, these two matters must not be confused, and if we read in a report that a tornado-cloud descends and strikes the earth, we must question the compe-

tence and the accuracy of the reporter. The light and dark clouds that are continuously rushing into the whirl at a high velocity and yet remain visible outside the whirl for a good share of the tornado's life, deserve equally careful examination, if care be possible when a tornado is near by. Judging by analogy with the inward-moving and outward-growing under edge of thunder-clouds, it ought to be possible to detect if the light and dark clouds of a tornado are similarly extended by growth in a direction opposite to the movements of their parts. Their colors also need explanation, and their positions in relation to light and shadows in the sky should be noted.

It is impossible to tell from many accounts whether the cloud mass, from which the funnel is pendant, exhibits any motion, rectilinear, spiral or circular. The clouds are often described as in commotion, but the quality of the commotion escapes the observer. Very few records give any indication of the height of the tornado funnel. This might be easily determined by an observer at a safe distance to one side of the track: a few measures of the angular altitude of the top of the funnel and its compass direction, and desirably the time of observation, would suffice. Afterwards, the position of the observer and the track of the tornado should be plotted on a map to scale; and the calculation would be then simple enough. Similar observations of the top of thunder-heads and of the cirrus outflow by two observers connected by telephone would be of great value in giving quantitative data with which to correct the curves of figure 6.

It is believed that tornadoes occur many miles within the western boundary of the area of southerly winds. Do the southerly winds reappear at the surface after the tornado has passed on? An excellent example of a moderately destructive thunder-squall of small dimensions, isolated within a large area of the hot southerly winds and clear sky, occurred in New England on July 21, 1885;* several hours later a much larger storm came on, and with its passage the wind changed to westerly. Are tornadoes similarly isolated? Such a question as this can hardly be answered

* Science. vii, 1886, 437. Proc. Amer. Acad., Boston, xxii, 1886, 45.

by single observers; but they might be by the combined observers of a single state in a single summer. If careful observations of temperature and clouds were added, as might be done in a fully developed system of volunteer observations, a most valuable picture of the conditions in which tornadoes arise would be gained. And we have confidence that this will be gained if the rate of progress of the last twenty years be maintained through the next.

19. *Conclusion.*—It is now for our readers to judge, if they have followed our pages to the last, how far the outline of Ferrel's theory here given is acceptable. It is manifest enough that its deductions as to the processes of tornado action run far beyond the facts of direct observation; but this is as it should be, for the success of a theory may be, in a measure, gauged by the light that it throws ahead on unseen phenomena. Although led by fact, the theory as a whole is highly deductive or imaginative; but it can be fairly said that the use of the imagination in framing the theory is thoroughly scientific; that is, it is guided by a full knowledge of associated facts, and of physical and mechanical laws pertinent to the discussion. The second step in the investigation is carried by Ferrel in his original memoirs through all matters bearing on the question in a manner that in this as in his other studies has placed him at the head of American meteorologists. No one else who has dealt with the subject has carried it so far and left his mark so indelibly upon it. Nor is the third step less carefully treated. The theory is tested by its quantitative competence to deal with the extraordinary violence of tornadoes; by its ability to correlate associated phenomena in a rational and not arbitrary manner; and by its prophetic indication of facts not recognized at the time. The admirable manner in which it bears these tests must gain it many adherents.

Through the whole study runs a current of keen and well-trained thoughtfulness, sharpening the eye in its observation of phenomena and scrutinizing their record, enlivening the imagination in its search for explanations and in its invention of hypotheses, and strengthening the reason in its critical judg-

ment of the whole. This current of thoughtfulness is the life blood of the investigation, and on the activity of its circulation from fact through suggestion to proof—that is, on the activity of careful theorizing, depends the growth of our science.

HARVARD COLLEGE, October, 1889.

ERRATA.

Page 346; eighth line from bottom, *Blanford* read *Hill.*
Page 349; third line from bottom, for *with the conduction* read *with and conduction.*

DIMINUTION OF TEMPERATURE WITH HEIGHT.

BY PROFESSOR H. A. HAZEN.

As I write this title I am reminded of a rather warm discussion between two eminent philosophers as to the moon's temperature. In this controversy, views of the utmost variance were presented and no satisfactory conclusion reached, as might have been expected. While the moon's temperature can be of only the least importance to us, yet it may be far otherwise with temperatures in our atmosphere. It might be thought that, since the moon is a quarter of a million miles away, a discussion of its temperature might be involved in a great uncertainty, but it should be a comparatively easy matter to obtain correct values within four or five miles of the earth's surface. This, however, is by no means the case, the problem is extremely intricate from the great variety of modifying conditions, of ascending and descending currents, of moisture contents, of clouds, etc., as has already been noted by Prof. Ferrel in this Journal for August, 1889. The most serious drawback to a good understanding of this subject is the lack of observations. We may say that a discussion of temperature under average conditions of the atmosphere must be of little value, since each condition delineated on our weather maps gives rise to a very different distribution of temperature. If we start out with the assumption that all our storms are produced upon variations of temperature and moisture, it will be seen that, until we obtain those on all sides and in the centre of our storms and clearing conditions, we shall be dependent upon doubtful and unsatisfactory theories.

There are at least two ways of examining the question. First, we may perform laboratory experiments and from their indications theorize as to nature's doings. Second, we may question nature herself.

It seems to me that thus far laboratory experiments have been of very little help. On the one hand a prominent physicist claims that dry air does not absorb the sun's heat but that aqueous vapor does, while another, equally as prominent, maintains that neither dry air nor aqueous vapor absorb the sun's heat but only liquid particles of moisture can intercept it. It is highly probable that under ordinary conditions, very little of the sun's direct heat is intercepted by the atmosphere within two miles of the earth's surface, and this is the only portion we need to study, since 95 per cent. of our storms occur below this limit. It is quite well known that at a height of a mile only, in the free air, the diurnal fluctuations of temperature are practically nothing. If this be granted, we have narrowed down our investigation enormously. The only way this can be positively proved is by making our observations in free air. Attempts toward such observations have been roughly approximated, up to the present time, from a lack of proper instruments. In balloon voyages differences of 20° have been observed in the same stratum going up and coming down. This difficulty has been entirely removed recently by the use of the sling psychrometer, which is capable of giving temperature within 1° in the same stratum up and down when traveling at the rate of ten feet per second.

An approximation may be had by observations on mountain tops. The writer of this article has recently spent several weeks on the summit of Mt. Washington, 6,300 feet above sea level. The observations conducted at the summit and along the sides have shown that the diurnal range of temperature is exceedingly small, and is not due at all to the heating of the air or fog by the sun, but only to the convection currents set up by the warm rocks of the summit. In one instance, while the black bulb thermometer rose 20°, and the temperature of planks 6°, that of the air rose only 1°.1. These results comprise the mean of seventeen observations between 9:35 and 11:28 A. M., and

twelve between 2:04 and 2:20 P. M. These figures are very significant and show that even liquid fog particles are not heated by the sun, since the summit was enveloped in fog throughout all the observations, though, as just stated, the black bulb was raised 20° even through the fog. The conclusion is almost unavoidable, from these and numerous other researches, that the distribution of air temperature in a vertical direction previous to a storm has nothing to do with the generation of the storm itself, and, we must look to other conditions advancing with the storm, for a correct interpretation of its action. It would seem as though many facts point in this direction. The sky may be perfectly serene and the first intimation we have of an approaching change is the appearance of high cirrus 300 or 400 miles in advance of the storm. Surely no changes of temperature distribution in a vertical direction are needed or indicated by this cirrus. It is an integral portion of the storm and entirely independent of conditions or ascending currents underneath it, and yet, it must be admitted, that this cirrus is the forerunner of the storm, and if changes in temperature are not needed for this, they are not needed for the succeeding cloud appearances and for the storm itself. The variations of air temperature on Mt. Washington are not due to the direct action of the sun from day to day, but rather to the onward progress of storms, or highs, or to changes in the wind direction. It is very plain that the effect of the sun's heat in the lower air strata, brought about by convection currents from the heated earth, must be greatly modified by the presence of clouds which tend to shield the earth. Some balloon observations have shown that underneath the clouds the temperature is nearly uniform for 2000 or 3000 feet. Innumerable observations with balloons and on mountain tops have shown that the present theories of an unstable equilibrium due to an abnormal vertical distribution of temperature are entirely unreliable. As an illustration of these last two points attention is called to a paper on "two balloon voyages" published in "Science," June 17, 1887. The temperature fell 3° in the first 1670 feet, then it rose 7°.3 in 780 feet, yet there was no commotion notwithstanding the abnormal temperature

distribution. Records of other voyages are in preparation which show an abnormal distribution of temperature far beyond what theory would indicate and followed by no commotion in the atmosphere. A paper published in this journal, October, 1887, shows that, on the approach of a storm to Mt. Washington, there is no marked change in the vertical distribution of temperature as theory demands.

It may be asked, what is the outcome of all this? I am free to admit that we have yet much to learn before we can make a good start even for a true explanation of storm phenomena. If anything has been done to show the utmost necessity of practical research, the accumulation of observations in a vertical direction, the unreliability of theories, the independence of storm action as regards the previous vertical distribution of temperature, the necessity of discarding general or average conditions, and of studying special phenomena, I shall be content.

September 18, 1889.

EFFECTS OF SEA AIR UPON TUBERCULOUS AFFECTIONS.*

The effect of sea air ought to be noticed not alone in consumption, but in tuberculosis which has not yet reached the consumptive period. When does tuberculosis begin?

Many anatomo-pathologists admit, with Friedlander, the tuberculous nature of any lesion in which may be observed the elementary follicle described by Köster. At the same time we ought to consider as tuberculoses: fungus arthritis, scrofulous adenitis, scrofulous abscesses of the skin and lupus, as well as Pott's disease. Whatever be the difficulty in establishing the exact line between scrofula and tuberculosis, histologically or clinically, it is, however, only in the progress of the disease that the difference is manifested. As long as the patient is in good hygienic condition, it seems as if the tubercle could scarcely progress from the embryonic follicle to the stage of granulation.

* Translated from a paper read by Dr. Hameau before the International Asso. of Climatology

This is especially noticeable upon the sea coast. With regard to this fact, the writings of Bergeron, Gibert, Cazin, Van Merris, Casse, furnish undoubted proof.

In the hospital of Berck, cures from osteitis, suppurated coxalgias and Pott's disease are in the proportion of 73, 71 and 30 per 100.

Many of these patients are cured without operation; their abscesses are absorbed. Pulmonary consumption is rarely combined with Pott's disease (Cazin). Regarding the patients in this hospital suffering from white swelling, Bergeron remarked: "Gradually, through the influence of this bracing atmosphere, the appetites of these unfortunate persons increased, and their strength was regained; articular fungus growths diminished in size, suppuration ceased, many of the fistulous openings healed." According to the opinion of these observers, mesenteric tuberculosis in its first stages was frequently cured by a long stay at the sea-shore.

The happy effect of this atmosphere upon all stages of scrofula is so well understood, that *seaside sanitariums* are erected in all civilized countries, of which the principal object is to regenerate the race, by the cure of this terrible diathesis which prevails most extensively in cities farthest removed from the seashore and which are unfavorable in respect to climate and other conditions of health.

We maintain, however, that these seaside places are not positively exempt from scrofula, and we refer to statistics arranged according to tables of exemption in military service. In Boudin's tables (1831–1853), twenty-four departments on the seacoast show eight scrofulous persons to one thousand free from such affection, while sixty-two inland departments are twelve to five.

If, in the seacoast departments, we compare the districts nearest the seashore with those farthest removed, which comparison has been made in Finistèrre (Bouton-d'Aguière), and in La Vendée (Lèques), we find that, deductions made of populous and crowded cities, the number of seacoast inhabitants affected by scrofula is very small. Hirsch, Arnould, Bertillon, and Rey

have observed the same facts. "Medical geography shows clearly the undoubted superiority of the seashore, and the beneficial influence upon scrofula. And, in this respect, the ocean is quite equal to the Mediterranean." (VanMerris.)

At Havre, scrofula, so frequent among children, is seldom seen in the adult, and rarely develops into pulmonary consumption.

Gibert, who observed this transformation for a number of years, clearly explained it through the modifying influence of the sea air. In 1844, Foucalt made the same observation: "At Sheveningen, scrofulous children recover and did not become consumptives when allowed to play in the open air."

All forms of scrofula, even those having almost reached the stage of tuberculosis, were cured or modified by a prolonged stay in the sea air. All physicians having any knowledge of this climate will be of the same opinion.

But if the sea air is the best modifier of the organism in scrofulous subjects and the most powerful obstacle to tuberculous degeneration, is it equally favorable for the cure of tuberculosis of non-scrofulous origin, and confirmed pulmonary consumption?

Here physicians do not agree, and facts on the one hand and the other appear contradictory.

For years it has been thought that sea climates and even sea voyages are beneficial to consumptives, while, in a justly celebrated memoir (1855), Rochard says that sea voyages increase the progress of pulmonary consumption; that that disease, far from being rare among sailors, is, on the contrary, more frequent with them than with those living on land, and that it prevails with equal intensity in the hospitals of our ports, marine stations and ships.

Up to the present time in which the importance of elevated climates is recognized, the sea air alone has possessed the confidence of invalids and physicians. It is scarcely possible that such a consensus could be maintained for centuries with nothing to justify it. Why then are ship surgeons the first to oppose the traditional opinion?

It may be, it is for the reason that they have made observations under particular conditions believing them to be general conditions, notwithstanding they have been made upon men subjected to many dangers of contagion and unhealthfulness. "There are few naval surgeons who have not noticed the frequent deaths of consumptives aboard ship or in maritime hospitals." (Rochard). All observations recorded in the memoir of Rochard are of robust men, who embarked in perfect health, some exceptionally strong and who have died in three, eight, twelve or twenty months. Now, the rapidity of this progress, of which the end is *always fatal*, is principally noticed in home prison and barrack epidemics, in persons infected by contagion and not predisposed to disease. Life at sea is quite similar to that of prison or barrack. If the sailor breathes heavily while working, he does not breathe properly, and quickly absorbs the unhealthy emanations of the hold and middle deck where he passes the hours of sleep. Ozone, which exists abundantly in the rigging, is less in quantity on the deck and within the hold (Jacotot, and Bourel-Roncière.) A single tuberculous patient may contaminate several persons and these, if they do not die during the passage, will largely increase the death roll of hospitals.

But, we may say, these examples prove, at least, that sea air does not prevent contagion nor the development of tuberculosis.

Certainly marine climate is not a specific. It does not act as a direct and positive antiseptic; but rather as a vivifying medium, or reconstructant. Marine atmosphere undoubtedly increases organic changes, vital power, and thus permits patients affected or theatened by this morbid agent to escape more easily. But this, upon condition that the body has not already been reduced by extreme suffering. So that it is unnecessary to say, that in such a sea-side resort may be found persons suffering from scrofula and tuberculosis; but we must ascertain if these subjects or valetudinarians are well situated, properly nourished, or clothed, having correct habits, are temperate, and conform to the necessities of good hygienic conditions, and if the number is or is not in proportion less than in

other localities further removed from the coast. This comparison is more in favor of maritime stations. Scrofulous persons, rachitics, and tuberculous subjects are rare there; adenitis, arthropathies, inflammation of the lymphatics, are nearly always cured, and rarely suppurate. The families of sailors are noted for their robust health.

Chest affections are not frequent among the people of healthful maritime stations. With regard to those attacked by chest diseases and who are sent to the sea coast for cure, sometimes there is hope of recovery for them, or at least relief, and prolonged life, if they are removed to the proper locality.

Sea air, such as is found in the temperate zones, presents, in fact, all the conditions sought for the cure of tuberculous diseases, Buffon terms it *constant*, in opposition to the *extreme* climate of interior countries. That is to say the difference between the day and night temperature, monthly and yearly is very slight. Atmospheric pressure is at the maximum, which facilitates respiration and organic changes. "Sea air is heavier, more moist, the temperature more equal, more homogeneous, less charged with electricity, less full of foreign matters; it presents a particular element, chloride of sodium. The influence of this atmosphere can only be healthful." (Fonsagrives).

Sea air contains only a little more oxygen than the inland countries and very little less azote and carbonic acid (Lewy); but it possesses a greater quantity of ozone and is not as full of organic particles. "This purity gives it precisely the healthfulness and the vivifying power which is not observed in the air of cities." (Arnould). "Marine air," said Gazin, "manifestly exerts a favorable action, preventive and curative in tubercularization, and this effect is not that produced by change from an ordinary climate. Country life, as seen by the results in the hospital of Forges proves this, and cannot be compared to a stay at the sea shore. There is then as a whole an effect which surpasses a simple modification of hygienic conditions."

On this point Prof. Verneuil expresses himself clearly: "I mean by *pure air*, that which contains no poisonous germ, and by *curative air*, that which has power to destroy. If the action

of pure air is very useful and sometimes sufficient to assure permanent surgical cures, more powerful still is that of curative climates. I give this name to the special centres where the cure of tuberculosis is attempted not alone by inhalation of pure air which is often charged by medicated properties, but also by the penetration of these principles through the respiratory, digestive and cutaneous ducts. In a word, sea side resorts, pine forests, sulphurous and arsenical springs are therapeutic centers."

This paper would be too long if we continued to cite authors of greatest authority who regard marine climates as favorable to treatment of tuberculosis. Hardy, Potain, Peter, and Jaccoud, consider them as prophylactic means. Casse, (Brussels), Mess, and Verhage (Netherlands), speak of cures of pulmonary consumption by a prolonged sojourn at the sea shore. The Germans advise a stay at the Norderly Island and the smaller islands of the North Sea. At Berck, Cazin has several times seen undoubted indications of pulmonary affections disappear. "I know of children," said Dr. J. Simon, "and adults, clearly in a tuberculous condition in whom the health has improved by a prolonged stay on the shores of the British Channel."

Physicians who practice by the ocean or Mediterranean shores give a large number of facts in favor of this cure. Monsieur Bergeron does not advise sending pronounced consumptives to the immediate sea-shore; "but he does not hesitate to send patients affected with tuberculous adenitis of the mesentery or of the bronchial tubes." William, who has observed for a number of years consumptives who had passed some time at maritime stations, estimates that from sixty to seventy out of one hundred showed marked improvement. Weber had almost the same opinion. "In many families, a yearly visit of several months at the sea-shore sufficed to destroy the germs of scrofula and consumption." (Weber.) With regard to a stay at Cannes, the same author made an observation of much interest: "In the autumn and spring of 1878–9, the weather was very severe. But according to the observations of the most distinguished physicians,

such as Dr. Frank and Dr. Marcet, observations which accord with ours, the result of the season was nevertheless very satisfactory, and our patients, *at least the consumptives*, were generally better than during the preceding winter. It is possible, however, that the unpleasant weather obliged them to be more prudent."

This explanation was not satisfactory to me, and I thought it necessary to seek elsewhere for the cause of the improvement which I have long noticed in our winter patients on the shores of the river Arcachon. I deemed it due to the greater moisture in the air and consequently to a greater quantity of ozone, conditions infinitely more favorable to many consumptives than dry air.

The cure of pulmonary tuberculosis is possible in all stages of the disease when the lesion is very slight; however, the chances of cure are much greater in the beginning of the disease.

The cure, or at least the amelioration of tuberculosis of slow progress, torpid in lymphatic subjects, slightly disposed to febrile reactions, may be obtained by a prolonged sojourn upon the borders of the ocean or the Mediterranean; while febrile, nervous patients suffer more at the sea-shore, and are much better on a marine coast that is protected by hills and surrounded by pine forests, the action of which is to lessen organic erethism and to permit the sea air to exercise its influence even upon those who are most nervous.

CONCLUSIONS.—Marine climate, which is the most powerful curative in scrofula, is very advantageous in the cure of bony, articular and ganglionic manifestations of tuberculosis. It constitutes, for the valetudinarian predisposed to tuberculization, a valuable preventive. It is also favorable to the consumptive who is in a situation to choose from among maritime localities those which are exciting or quieting, and which are most in harmony with his condition.

THE INTERNATIONAL METEOROLOGICAL CONGRESS AT PARIS.

By A. Lawrence Rotch.

In accordance with the notice published in the August Journal, an International Meteorological Congress was held at Paris, between September 19 and 26, 1889. The meetings took place at the rooms of the Societé d'Encouragement, except the opening and closing sessions which were at the Trocadéro Palace. There were no delegates appointed by either Germany or Austria for political reasons, and Russia, Holland, Belgium, etc., were also unrepresented, but, on the other hand, there were present delegates from such distant places as Japan and the South American states. The Congress, being an unofficial one, had no power to make resolutions or recommendations, but the suggestions resulting from the papers and discussions will no doubt have their effect upon the directors of the meteorological services and observatories who attended the Congress.

M. Mascart, the director of the French Meteorological office, welcomed the members of the Congress in the name of the minister of Public Instruction and declared the Congress open. The following officers were then appointed:

President: M. Renou, president of the French Meteorological Society and director of the Park of St. Maur observatory.

Vice-Presidents: Messrs. Symons (England), Rev. Fr. Denza (Italy), Hildebrandsson (Sweden), Billwiller (Switzerland), Paulsen (Denmark), Pujazan (Spain), Cruls (Brazil), and Gould (United States but formerly in the Argentine Republic).

General Secretary: M. Léon Teisserenc de Bort.

Secretaries: Messrs. Moureaux, Lasne, Abbe Maze and M. Lancaster, of Belgium, who was absent.

The President in his opening address spoke of the natural division of meteorology into statical and dynamical meteorology, both of which could profit by the reunion of a Congress, the first in climatology, for which a uniform method of observation was necessary, the second for weather prediction in which the coöperation of a network of stations should be sought for.

M. Mascart presented a copy of the *International Meteorological Tables*, published under the auspices of the International Meteorological Committee by the resolution of the Roman Congress. These tables have their headings in French, English and German and will be sold at 35 francs a copy. They will probably be ready for distribution to sub-

scribers in the course of a few months. (For further details concerning this important work see this JOURNAL for September, 1889.)

The following sessions of the Congress for the discussion of the programme which had been prepared were presided over successively by the vice-presidents, with two exceptions. M. Hildebrandsson commenced the programme by presenting a report on the classification of clouds which had been printed and distributed to the members of the Congress. The classification reduces the number of forms to the ten following.

CIRRUS.

Cirro-cumulus.	Cirro-stratus.
Cumulo-cirrus or alto-cumulus.	Strato-cirrus or alto-stratus.
Strato-cumulus.	Nimbus.
Cumulus.	Cumulo-nimbus.

STRATUS.

M. Hildebrandsson showed a series of cloud photographs executed at Upsala and a series of oil paintings made in Sweden and at Hamburg in accordance with his classification and that of M. Abercromby. These paintings will soon be reproduced by chromolithography (see this JOURNAL, December, 1889.) In a discussion of this report the Abbe Maze proposed another radically different classification, designating the clouds by two words expressing the kind and species.

The Rev. Fr. Denza communicated a memoir on the vertical decrease of temperature in Italy. The mean for the year gave for a decrease of 1° C. 192 m. for the whole of Italy, but in the Aoste valley only 159 m. In winter the figures were 289 m. and 189 m., respectively, which latter coincide with those found between Pike's Peak and Denver, which are 187 m. for winter and 159 m. for the mean of the year. The difference of level of the stations in the Alps is 2,200 m. and in Colorado, 2,700 m. It often happens that the air temperature rises to a certain height and then diminishes. This effect is most noticeable in winter and has never been more marked than in January, 1887, when the temperature at 700 m. was 7° C. higher than at 200 m. after which it decreased at the ordinary rate. During this month the ground was covered with snow, the barometric pressure was high and the air was calm and dry. The author concluded that the problem was complex for mountainous regions and that more observations were necessary. In the discussion which followed it was pointed out that there should be a distinction made between observations during calm and during windy weather, and in the last case whether the wind ascended or descended the mountain flanks; also the wind direction at each station should be noted, for if the directions are different the results of the comparison are doubtful. M. Billwiller said that the diminution of temperature differs for neigh-

boring localities and doubtless depends on the configuration of the ground, and that therefore no absolute relation can be established between the altitude and the range of the variation. The temperature of the valleys must in any case be left out of account. The law depends upon the manner of chosing the station, but in winter the question is simpler because there is less stagnation, and as soon as the air is in motion the law of the decrease is established.

M. Wada gave the results obtained by ascents of Fusiyama in Japan. In August, 1880, simultaneous observations at the top of this mountain (3,700 meters above sea-level), and at its foot gave a decrease of temperature of 1° C. for 182 m., or 0.55° for 100 m , vertical elevation; this number appears smaller than it should be, because the observations, which lasted three days, were made only during the daytime. Another ascent made in September, 1887, gave a decrease of 1° for 168 m., or 0.59° for each 100 m. It is proposed to make an ascent every year of Fusiyama for physical experiments.

Rev. Fr. Dechevrens said that the question of variation of temperature with altitude had a particular interest when considered with regard to the variation of atmospheric pressure. Thus he had shown that if with high pressures the temperature is relatively very high on the mountain summits and very low in the valleys and plains, the inverse occurs with low pressures. In a word, the approach of a cyclone produces heat in the lower strata of the atmosphere and cold on the mountains, just as the approach of an anti-cyclone produces the reverse phenomena. These phenomena do not depend on the wind direction as has been supposed. Thus at Zi-ka-wei, in China, in the midst of a vast plain, whatever quarter the wind came from, when the barometer fell there was almost always a rise of about 10° for a fall of 20 mm. in the pressure. On Mount Washington, on the other hand, where the northwest wind blows almost constantly, an equal fall of the barometer brings generally a fall of nearly 30° in the thermometer. This phenomenon should find an explication in any rational and complete theory of atmospheric cyclones.

M. Adam Paulsen communicated the results of measurements in Greenland on the elevation of the auroræ boreales above the ground, obtained by means of two theodolites on a base of 5,800 m. Measures in temperate regions have given a height of 200 km. and more, but here it was found that the auroræ descended sometimes to within 600 m. of the fiord, but at other times rose to 60 or 70 km. It is thus shown that though the height of auroræ is very variable, there is no stratum particularly favorable for their formation. It results from the comparison of the tables of frequency of auroræ with those showing the frequency of sun spots during the same periods, that the maximum frequency of auroræ corresponds to the minimum of solar activity, while in temper-

ate regions precisely the opposite occurs. In the same way the amplitude of the diurnal variation of the magnetic needle in temperate regions increases with the number of sun spots, while, according to the author, the contrary occurs in the polar regions, so that the parallelism between auroræ and the magnetic needle obtains in all latitudes.

M. Teisserenc de Bort presented on the part of M. Cérasky a notice of the luminous clouds seen at Moscow in 1885 and 1886. The height of these clouds was approximately determined to be 75 km. These clouds owed their light to the sun, and were only seen when the sun had descended a little below the horizon. They were absolutely transparent, but were sufficiently luminous to be photographed. The coincidence between their disappearance and that of the sky glows was remarked. The variations of actinometric measurements, even when the sky was clear, have led M. Crova to admit the presence from instant to instant of thin veils invisible to the eye, and photographs of a very blue sky have shown fine striæ, analogous to cirri, which were quite invisible otherwise.

At the second meeting M. Angot discussed the first comparative observations of wind velocity on the summit of the Eiffel tower and at the Central Meteorological office. Up to the 31st of August, 71 days of observations gave the following results of the diurnal variation of the velocity: At each station the diurnal curve showed a chief maximum and a chief minimum; at the meteorological office the minimum (1.5 m. per second) occurred about 4:30 A. M. and the maximum (3.2 m. per second) about 1 P. M., this being the ordinary variation at low stations. On the summit of the Eiffel tower, on the contrary, the minimum (4.9 m. per second) was at a little before 9 A. M. and the maximum (9 m. per second) occurred towards 11:30 P. M., which resembles the *régime* of the wind on mountains. The relation of the velocities was at its maximum, 5, from 2 to 4 A. M.; it was at its minimum, 2, from 9 A. M. to 3 P. M. It is interesting and wholly unexpected to find at 300 m. above the ground the diurnal variation in wind velocity which hitherto has only been observed on high mountains.

M. Hepites described the organization of the recently established Roumanian meteorological service, and the Rev. Fr. Denza made some general deductions from tables showing the mean monthly and annual temperatures at Italian stations. M. Sieur considered the secular changes of climate, and sought to refute the arguments explaining the variations of temperature by the displacement of perihelion. In the discussion which followed it was the general opinion that no secular variation of climate could be inferred from the limits of forests, vineyards or glaciers, the dates of the freezing of lakes and rivers and the time of harvests, or from the temperatures of thermal springs.

M. Symons exhibited and explained his new instrument called a bron-

tometer, constructed by Richard brothers. This is a registering instrument permitting the time of the lightning, the beginning and ending of the thunder, rain and hail to be noted by means of keys. The instrument records automatically at the same time the smallest variations in the barometric pressure and the velocity of the wind, and it is expected that it will be of much value in studying the cause and relation of the various phenomena of a thunder-storm.

M. Teisserenc de Bort showed some remarkable cloud photographs of M. Paul Garnier which are the result of much experimenting with the various photographic apparatus and plates.

At the next meeting M. Rotch described the apparatus employed at the Blue Hill Observatory for measuring the movement of clouds and for registering the cloudiness during the night. A description of the nephoscope and of the methods employed in the former work will be found in Vol. XX, *Annals of the Observatory of Harvard College.* To register the cloudiness during the night an apparatus invented by Prof. Pickering is employed consisting of a photographic camera with very sensitive plates directed to the pole star. An automatic shutter closes the camera before dawn. If the night was clear the trace of the pole star is represented by an arc of a circle which is broken when clouds pass before the star. These interruptions measure the cloudiness, and the results obtained do not differ a tenth from the means of direct observations.

M. G. Lemoine described the progress accomplished since 1878 in the chief river basins of France with respect to flood warnings. The administrative organization directed by a commission has become quite general, while the technical studies pursued in the various basins result in flood warnings which are in some cases given four days in advance.

The Congress expressed the wish that in each State the system of pluviometric and hydrometric observations should be extended as much as possible by the proper authorities in order to permit a more complete study of precipitation, the extreme and mean discharge of streams of water and the influences which modify their relations.

M. Ritter explained a mode of notation by which the absolute intensity of a phenomenon was indicated by a coefficient *meteorograde*, representing the relative degree of intensity of this phenomenon, or the relation which its actual intensity bears to its maximum intensity in the place under consideration. M. Ritter exhibited some charts, constructed after his method, of hydrological phenomena and suggested its application to the variation of the barometer.

The Abbe Maze elaborated his binary cloud classification modeled after the classification of Linneus, which is used by naturalists. M. Hildebrandsson replied that in advocating with M. Abercromby a modification of Howard's cloud classification he acted from a practical point

of view, and said that it was unwise to burden the memory of observers with a complicated nomenclature. The Rev. Frs. Ferrari and Denza sustained M. Hildebrandsson.

M. Teisserenc de Bort defined the difference between the origins of barometric gradients, showing that the gradient could generally be resolved into two parts—the motor gradient which caused the motion and the resisting gradient which is a consequence of the movement, and which only acts to balance the action of the centrifugal force. He stated that this distinction between the gradients in a barometric depression had a practical importance in weather prediction.

M. Symons showed two photographs of lightning flashes taken by M. Weber on a plate moved laterally. The trace was indicated by a band instead of by a network of discharges, proving that the duration of the flash is quite appreciable.

At the following meeting M. Cornu described the photo-polarimeter which resolves in a simple manner the problem of the polarization of the light from the sky. The light is received on a Wollaston prism, by means of which the two images are polarized at right angles, and which, with the light from the sky, are of unequal brilliancy. A Foucault analyser of Iceland spar, interposed in the path of the rays, is turned until the two images are equal; and the angle through which it is turned being measured, the proportion of light polarized is obtained by a formula. The use of this instrument, which gives exact indications on a scale of 100°, was recommended to meteorologists, since it had been found that the sudden change in polarized light corresponds always to a marked change in the meteorological conditions, and this before the other atmospheric phenomena give any signs of a change.

M. Raulin presented a memoir on rain periods. Like the mean temperature, the evaporation follows a certain seasonal law, and the precipitation gives a similar curve when the means of a long period are used. For continental climates the curve has about the same form as that of the temperature, but in approaching the coast the curve becomes almost the inverse of the temperature. Charts were shown in which the regions under these regimes were distinguished by different colors.

M. de Montessus stated the results of his investigations on the diurnal distribution of seismic shocks and their pretended relation to lunar phases. For this purpose he compared 45,000 seismic disturbances distributed over the globe. There is a faint maximum during the night but this disappears when the stronger shocks are considered. The distribution throughout the phases of the moon is nearly uniform and the author hopes to be able to demonstrate that the seismic disturbances are independent of exterior influences. M. Wada remarked that the observations made in Japan gave entirely contrary results to those of M. de Montessus, as it was shown by more than ten years' observations

that the earthquakes were more frequent during the night than during the day and that there was a slight increase during the interval from the last quarter to the new moon over the number during the other quarters.

M. Angot read a report on the observations of vegetative phenomena, the migration of birds and the appearance of insects with a view to arrive at uniformity in the instructions given to observers, especially in regard to the notation. M. Teisserenc de Bort read a report by M. de Touchimbert on the quantity of heat necessary to bring wheat to maturity at Poitiers. In the discussion which followed the local influences of topography on temperature were quoted.

M. Sieur presented a paper on the tracks of fourteen thunder-storms in southwestern France. He spoke of the influence of valleys and watercourses upon the direction of storms and remarked their appearance in series having nearly parallel paths.

Lieut. Ward, U. S. N., exhibited charts and logs of the U. S. Hydrographic office and stated that this bureau is prepared to receive, publish and distribute speedily all meteorological data which are sent to it, in a useful form for navigators and meteorologists. The office is also ready to furnish its information to any other office which desires to cooperate with it. Regret was expressed that the series of international observations, organized by the Vienna Congress of 1873 should have been abandoned.

The aid of the Congress was asked to supply information which might assist in the preparation of meteorological charts of the seas south of the equator, a work soon to be undertaken by the Hydrographic office.

On the afternoon of the 24th, M. Moureaux read a paper by M. Ellis, of Greenwich, on the relations existing between astronomy, meteorology and terrestrial magnetism. Most astronomical observatories are provided with accurate and powerful apparatus and their number is sufficient for the actual needs of the science. In meteorology, on the contrary, a great number of observatories are necessary and the united action required justifies the reunions of congresses. Magnetic phenomena being of a more general nature it is not necessary that the observatories should be numerous if well distributed. M. Ellis mentioned the relation of magnetic phenomena to sunspots and stated the following desiderata: (1) the establishment of permanent magnetic observatories in regions where they are lacking, especially in the Southern hemisphere; (2) the exact registration of the time on the magnetic curves; (3) the publication by the different observatories of a certain number of curves of perturbations on days to be agreed upon; (4) the development of the theory of earth currents which are in close relation with the irregular variation of magnetic phenomena. M. Moureaux

stated how far these conditions were fulfilled in France and the colonies, and M. Mascart explained why the short magnets employed in the French magnetographs were preferable to the large magnets used in the Adie and other foreign instruments.

M. Mazoyer explained the method used in making flood predictions on the Loire. By means of the maximum heights of the water observed at well-chosen points up-stream, the maximum flood can be calculated for a point situated farther down and warnings given by telegraph or special telephone to interested persons.

Dr. Fines stated the results of his comparisons between the Robinson and Bourdon anemometers, from which it appeared that the former always gave a less velocity than the latter, though the mean difference did not exceed 6 m. with a mean velocity of 30 m. per second. Dr. Fines mentioned the importance of indicating the height of the anemometer above the ground in any series of observations, since it had been found that the wind velocity at an altitude of 30 m. was nearly double that at the surface of the ground.

M. Renou described the necessary conditions for a good thermometer shelter. A simple roof, inclined towards the South, having a screen of oil cloth stretched a little above and with two lateral isolated screens permitting the free passage of air on all sides, constitutes the best shelter. The thermometers should be placed slightly below its lower edge and controlled by a sling thermometer, especially in the morning and in the evening.

M. Dufour exhibited a new condensation hygrometer in which the dew-point is determined in the plate of silvered brass on which the dew is deposited. The simplest form is a polished bar with a thermometer inserted in each end and provided with a graduated scale. One end being cooled by dropping ether upon it, the position of the limit of the dew is noted and the corresponding temperature is obtained by the interpolation from the readings of the two thermometers.

At the next meeting M. Piltschikoff, after citing the anomalies presented by the isomagnetic lines experimentally determined in Europe and America, insisted upon the importance of a theoretical study of these lines and their variations. He explained a graphic method of obtaining the diagrams of the various isomagnetic lines corresponding to a unipolar anomaly. In answer to M. Gossot, M. Mascart said that although the relations between the position of the sun or the planets and magnetic phenomena had long been sought, these relations were absolutely fanciful, which opinion is now universally held by meteorologists.

M. David presented a note on the employment of semaphores for the dissemination of local weather forecasts in the department of the Yonne. M. Hildebrandsson explained the system employed in Sweden to trans-

mit the weather conditions by means of 114 charts of weather types, which are numbered, and complete sets distributed to the railway stations and ports. It is, therefore, only necessary to telegraph the number of the proper chart to have the corresponding signal displayed.

M. Poincarré gave a *resumé* of his researches on the relations between the positions of the moon, the displacement of the limits of the trade winds and the barometric changes. The displacements of the region of the trades for two years were found to be proportional to the amplitude of the lunar oscillations and the passage into perigee or apogee was accompanied by barometric changes whose combination produced a sudden fluctuation of a millimeter in the gradient, and corresponding oscillations in the trade-wind limits.

M. Billwiller stated the theory of the diurnal variation of the wind at elevated stations which was first suggested by Espy, elaborated by Köppen, and confirmed by the observations made in 1883 on the Sentis.

M. Lasne developed his theory of the gyratory movements of the atmosphere which he had already presented before the French Meteorological Society. He supposes that these movements have a general dynamic and not a local thermic origin, and that they are due to the lateral friction of the permanent winds situated at a great altitude.

The Rev. Fr. Dechevrens presented a note on the observations of the inclination and of the vertical component of the wind at Zi-Ka-Wei, China. They show that, at a height of 40 m., the general movement of the air is upward at an angle slightly exceeding 6°. During the day the direction of motion is very variable, but during the night the wind always ascends, and more strongly in winter than in summer. If the inclination of the wind in winter be compared with the corresponding barometric heights, it is seen that the movement of the air is clearly upwards during barometric depressions, and as a general rule the velocity is greater as the barometer is lower. It was remarked that the curve representing the mean variation of the wind at Zi-Ka-Wei, in 1886, was exactly the reverse of the curve of the variation of the atmospheric electricity at Perpignan. The Rev. Fr. Dechevrens described the apparatus successfully used by him, and proposed now to replace the cup anemometer, which gave neither the horizontal component nor the absolute value of the wind velocity, by one having vertical semi-cylinders upon which the vertical component of the wind could have no action.

At the following meeting, M. Raulin considered the rain periods for South America and divided them into seven seasonal types. M. Wada presented a study of thunder-storms in Japan based on the documents of the Tokio Observatory since 1875 and upon the recent data from thirty-five stations of the second order. The results show that the frequency of storms increases towards the north, and seem to indicate that the frequency is also greater in the interior and in elevated regions than

on the coast. The damage by lightning and hail is less in Japan than in Europe on account of the light and low form of the buildings, but nevertheless the government is about to require industrial buildings to be provided with lightning rods under the supervision of the telegraph department.

The Rev. Fr. Dechevrens stated that in Japan he had found a maximum in the spring and a more marked one in the autumn; in China, a single summer maximum with no winter storms; at San Fernando, two nearly equal maxima in the spring and autumn, and on the Congo, from one year's observations, the autumn maximum is less than that of the spring. The curve of the frequency of cirri presents the same form for different localities. M. Hildebrandsson had found in Germany a secondary maximum in the spring and a chief maximum in the autumn; in the north of Sweden there is a prolonged maximum in the summer while in the northern part of the country the thunder-storms are confined to the warmest months. He had not remarked the concordance of the cirrus. M. Mascart remarked that in France as in Japan the severity of thunder-storms increased inland.

M. Wada proposed a uniform system of storm signals similar to the Japanese, for international adoption. On motion of M. Mascart the Congress expressed the wish that the system of storm signals should be rendered uniform as speedily as possible and referred the question to the International Maritime Conference in session at Washington.

M. Teisserenc de Bort gave a *resumé* of his memoir on the distribution of barometric pressure over the globe. The equatorial minimum observed is easily explained by the difference of temperatures, but the cause of the tropical maximum is not so clear. Ferrel has stated the effect of the relative movement, but the author's theory of the annular barometric maxima differs in believing that the causes alleged by Ferrel only act to increase the maxima. In their relative motion with respect to the ground the winds thus created outstrip the latter's movement and describe a curved path, the velocity being reduced by friction in the ratio assumed by the author to be the square root of the calculated velocities. In its movement towards the poles the air meets parallels where the value of a degree of longitude becomes smaller and smaller, whence results the accumulation of air which causes the polar maximum. The author has calculated the form of a surface of equal pressure at a height of about 4,000 m. and knowing the temperature of the lower strata it was easy to calculate the barometric pressure at the surface of the earth. The isobars drawn with these data agree fairly with the observed isobars, thus demonstrating the truth of the theories set forth.

M. Hildebrandsson said he had observed the mean direction of atmospheric currents, independently of any theory. He had recognized in

the neighborhood of depressions a convergence of the winds at the earth's surface; from 2,000 to 3,000 m. the movements are nearly circular, and in the cirrus region the motion is always divergent. His work together with that of M. Ley permitted him to establish wind roses for almost all the countries of the world. The data embodied in two charts, one for summer the other for winter, showed that the cirrus moves towards the west in equatorial and towards the east in temperate regions. In the north of Europe a slight deviation towards the southeast is remarked in winter. The cirri thus appear to follow the same paths as the great barometric depressions. M. Hildebrandsson exhibited the nephoscope of Fineman adapted for use on board ship.

M. Lasne remarked that the vertical movements of the air observed by the Rev. Fr. Dechevrens were incompatible with the horizontal wind velocities noted, which must, nevertheless, furnish the supply or escape of the necessary air. The Rev. Fr. Dechevrens replied that he did not think that the heating and cooling of the tower exerted any influence, since he observed generally the descending movements during the day and the ascending ones during the night. Vertical currents also occurred when there were no horizontal winds. These facts were independent of any theoretical considerations.

M. Teisserenc de Bort presented on the part of M. Renou a note relating to the uniform notation of fog, days with rain, etc. At the park of St. Maur the scale of fog used is when objects are hidden at 15 m. The last Meteorological Congress recommended that rainy days should be those on which at least 0.5 mm. fell, but the author considers that the moistening of the pavement is sufficient evidence for the purpose. In the days with thunderstorms he would also include those on which the faintest thunder was heard.

M. Richard described an aspiration anemometer recently installed at the Paris Meteorological Office on Hagemann's principle, consisting of a vertical tube terminated by a truncated cone which is open at its smaller base. The aspiration produced by the wind in this apparatus is registered by means of a very sensitive manometer. Dr. Fines described a modification of the Hagemann anemometer in which the effect of the wind was increased.

At the closing session of the Congress, Dr. Fines presented a note on the variations of atmospheric electricity observed at Perpignan, alluding also to the difficulties caused by spiders' webs on the apparatus and the effect of humidity on the suspension of the needles of the magnetometers. M. Moureaux described the methods employed in the last instance at the St. Maur observatory. The discussion of the curves of atmospheric electricity at the College de France shows the third oscillation towards the middle of the day mentioned by Dr. Fines but it is not found at St. Maur and it is nearly insensible at Lyons. At the lat-

ter station the absolute minimum occurs in the morning instead of in the evening as at all the other stations discussed.

M. Mascart observed that the potential of the electrometer is especially influenced by the masses of air which touch it and that its indications depend upon the objects over which the wind has passed. He replied to those persons who wished electrical observations made on the summit of the Eiffel Tower, that, notwithstanding its height, the difference of potential between the top and the ground was zero.

M. Teisserenc de Bort presented a note on the part of M. Piche formulating a new meteorological law. The author supposes the sun's heat to be constant and to be distributed between the atmosphere, which it sets in motion, human beings, animals and plants. Thus, if one of these modes of utilizing this heat be increased, the others will necessarily be diminished; so that if man could favor the development of organic life, the heat available for putting the air in motion, and consequently storms, might be decreased. In a discussion which followed on the possible influence of man on climate, it was the general opinion that the effect could only be local or indirect.

M. Rotch read in abstract a paper by M. Clayton upon the classification of clouds according to the general system of Abercromby and Hildebrandsson, but with special reference to their origin.

M. Moureaux spoke of the development of magnetic studies in France since the establishment of the Central Meteorological Office. There are now in France ten magnetic observatories, at eight of which the variations of the various elements are regularly registered. The magnetic charts of France, based on the observations of M. Moureaux at more than eighty stations, having shown certain anomalies, new and more detailed charts are to be prepared, based on the observations made at the chief towns, at all the ports, and at certain special points indicated by the geological charts. This work will be completed in five or six years.

The Rev. Fr. Denza spoke on the relation of earthquakes and terrestrial magnetism, and M. Teisserenc de Bort presented his memoir on the reduction of the barometer to sea-level.

M. Mascart on the part of M. Renou, who was ill, thanked the members of the Congress, and especially the foreigners, for their hearty coöperation and congratulated them upon the cordiality and good feeling which had characterized the meetings. The Rev. Fr. Denza replied that although he had heard congresses were useless, yet he believed that they were not only beneficial to the science but to the scientists, who acquired there personal relations with one another which were of great advantage. In the name of all the foreign members he bade an affectionate farewell to the French meteorologists, and especially to those who had directed the Congress, which he thereupon declared closed.

The following excursions and visits took place during the sessions of the Congress: On September 20th a visit was made to the Central Meteorological Office, where, in addition to the regular installation, the experimental apparatus of M. Weyher to illustrate the formation and action of cyclones, tornadoes and waterspouts was exhibited in action. The collection of registering instruments of Richard brothers at the Exposition was inspected the same afternoon. The next day an excursion was made to the park of St. Maur, where the meteorological and magnetic observatories were shown by Messrs. Renou and Moureaux respectively. The Eiffel Tower was ascended in order to examine the Richard instruments installed in the meteorological observatory on the top, some of these instruments registering their indications at the ground. On the last day of the Congress the foreign delegates and members were entertained by their French associates at luncheon at a restaurant in the Exposition, and in the evening the principal delegates dined at the house of M. Teisserenc de Bort, Senator.

ERRATA IN METEOROLOGY AT THE PARIS EXPOSITION.

PART I.

In the description of the radiometer exhibited by the Montsouris Observatory, for "a counter of revolutions" substitute "permitting the revolutions to be counted."

In Richard brothers' exhibit of the anemometer for the vertical component of the wind, for "Parrigou-Lagrange" read "Garrigou-Lagrange." In the description of the same instrument, in the abscissæ representing "turns" read "times."

In the anemometer described in the last paragraph, for "Bourdan" read "Bourdon."

PART II.

In the description of the barometers exhibited by Usteri-Reinacher, for "Goldschmidt" read "Goldschmid."

In the Russian section, for "Timtshenks" read "Timtschenko."

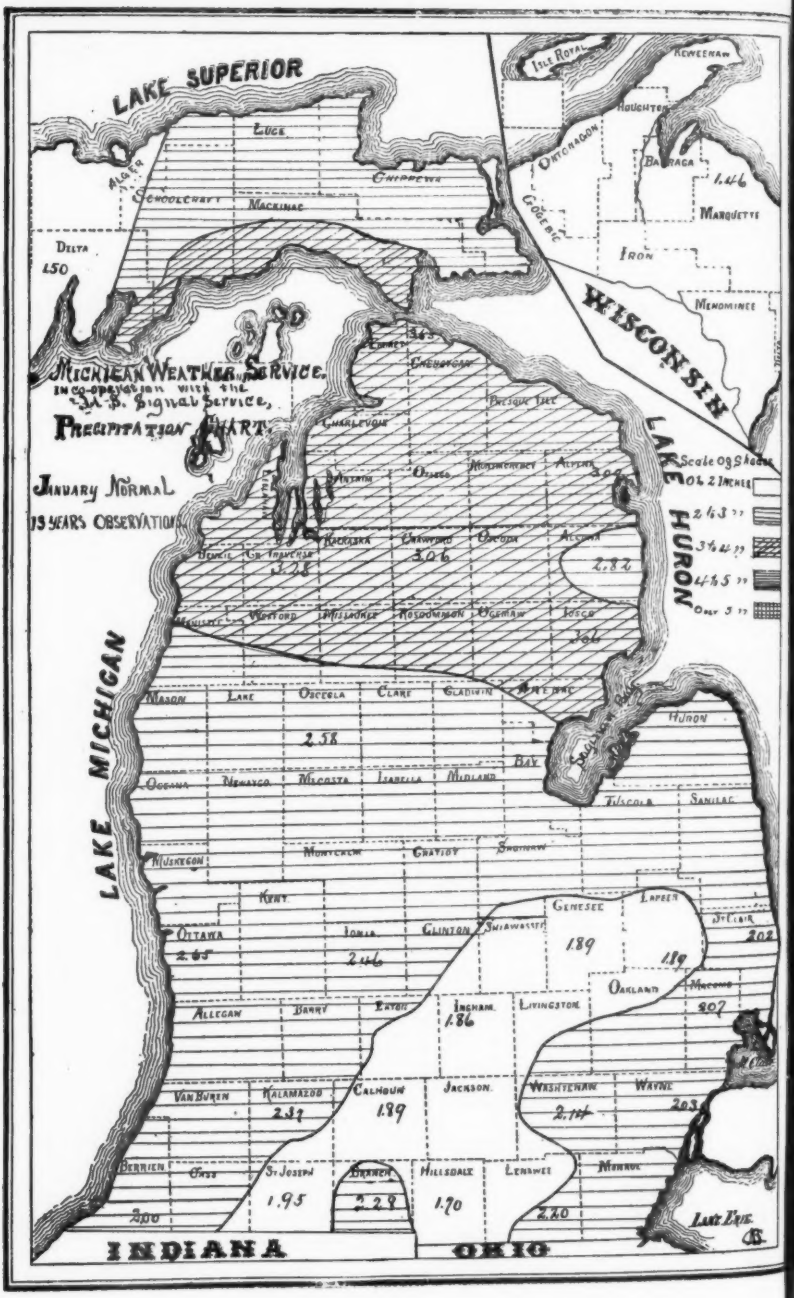
RAINFALL IN MICHIGAN—FEBRUARY.

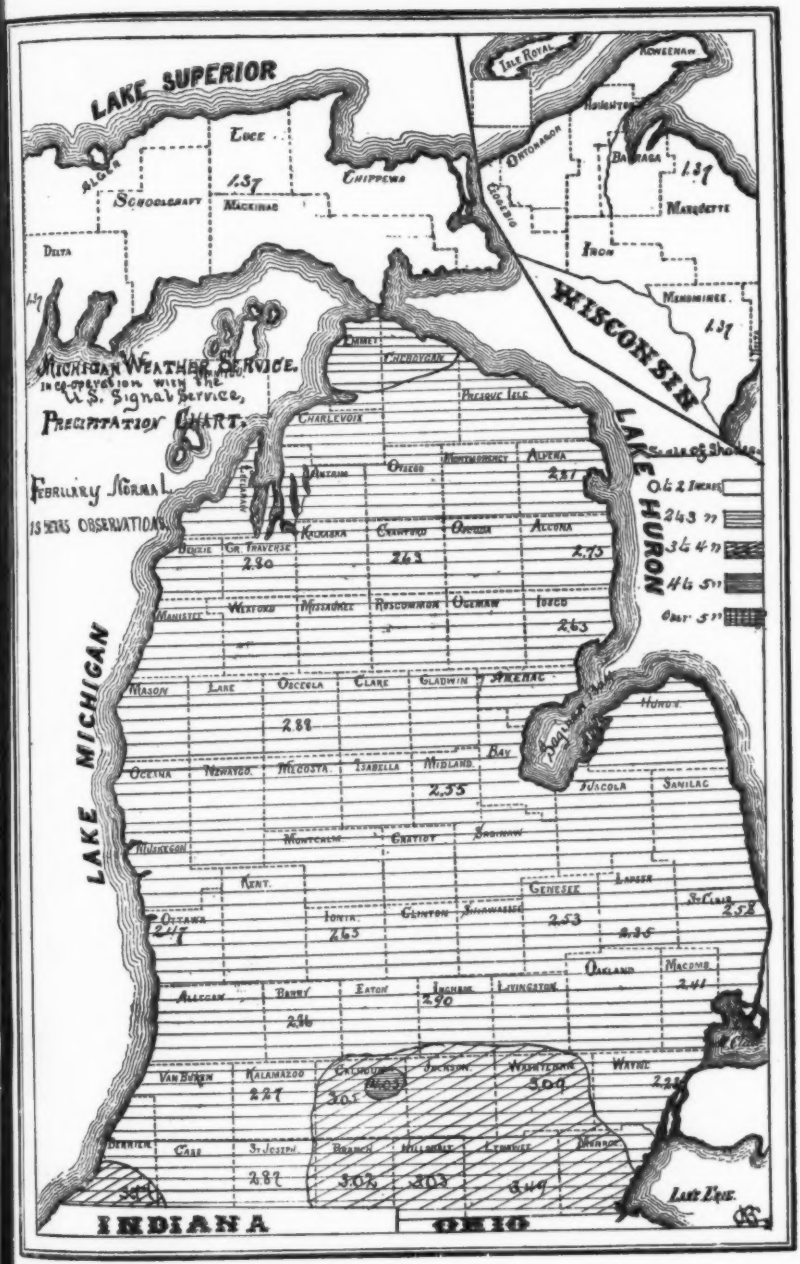
By N. B. CONGER.

Director State Weather Service.

The distribution of rainfall for the month of February increases in amount from the upper peninsula to the southern line of the state. The average for the upper peninsula being 1.37 inches, and that of the northern section, 2.63 inches; the central section, 2.55 inches; and the southern section, 3.16 inches, while the average for the State is 2.80 inches.

The light rainfall in the upper peninsula for the years 1872 to


LAKE SUPERIOR
Isle Royal
Keweenaw
Houghton
Ontonagon
Baraga
Marquette
Iron
Menominee
Gogebic
Delta
Schoolcraft
Mackinac
Chippewa
Luce
Alger
WISCONSIN
LAKE HURON
LAKE MICHIGAN
MICHIGAN WEATHER SERVICE.
IN CO-OPERATION WITH THE U.S. Signal Service,
PRECIPITATION CHART.
JANUARY NORMAL
13 YEARS OBSERVATION.
Scale of Shades
0 to 2 Inches
2 to 3 "
3 to 4 "
4 to 5 "
Over 5 "
Emmet
Cheboygan
Presque Isle
Charlevoix
Antrim
Otsego
Montmorency
Alpena
Kalkaska
Crawford
Oscoda
Alcona
Grand Traverse
Leelanau
Benzie
Manistee
Wexford
Missaukee
Roscommon
Ogemaw
Iosco
Mason
Lake
Osceola
Clare
Gladwin
Arenac
Huron
Saginaw Bay
Bay
Oceana
Newaygo
Mecosta
Isabella
Midland
Gratiot
Tuscola
Sanilac
Muskegon
Montcalm
Shiawassee
Kent
Ottawa
Ionia
Clinton
Genesee
Lapeer
St. Clair
Allegan
Barry
Eaton
Ingham
Livingston
Oakland
Macomb
Van Buren
Kalamazoo
Calhoun
Jackson
Washtenaw
Wayne
Berrien
Cass
St. Joseph
Branch
Hillsdale
Lenawee
Monroe
Lake Erie
INDIANA
OHIO
1.46
2.50
2.58
2.65
2.46
1.89
1.89
2.07
1.86
2.37
1.89
2.03
1.95
2.29
1.70
2.20
2.00


LAKE SUPERIOR
ISLE ROYAL
KEWEENAW
HOUGHTON
ONTONAGON
BARAGA
MARQUETTE
ALGER
SCHOOLCRAFT
MACKINAC
CHIPPEWA
DELTA
IRON
MENOMINEE
WISCONSIN
MICHIGAN WEATHER SERVICE.
IN CO-OPERATION WITH THE
U.S. Signal Service,
PRECIPITATION CHART.
FEBRUARY NORMAL
13 YEARS OBSERVATIONS
EMMET
CHEBOYGAN
PRESQUE ISLE
CHARLEVOIX
MONTMORENCY
ALPENA
OTSEGO
ANTRIM
LEELANAU
BENZIE
GR. TRAVERSE
KALKASKA
CRAWFORD
OSCODA
ALCONA
MANISTEE
WEXFORD
MISSAUKEE
ROSCOMMON
OGEMAW
IOSCO
LAKE MICHIGAN
LAKE HURON
0.42 INCHES
2.43 "
3.44 "
4.45 "
OVER 5 "
MASON
LAKE
OSCEOLA
CLARE
GLADWIN
ARENAC
HURON
SAGINAW BAY
OCEANA
NEWAYGO
MECOSTA
ISABELLA
MIDLAND
BAY
IOSCO
SANILAC
MUSKEGON
MONTCALM
GRATIOT
SHIAWASSEE
KENT
GENESEE
LAPEER
ST. CLAIR
OTTAWA
IONIA
CLINTON
SHIAWASSEE
OAKLAND
MACOMB
ALLEGAN
BARRY
EATON
INGHAM
LIVINGSTON
VAN BUREN
KALAMAZOO
CALHOUN
JACKSON
WASHTENAW
WAYNE
BERRIEN
CASS
ST. JOSEPH
BRANCH
HILLSDALE
LENAWEE
MONROE
LAKE ERIE
INDIANA
OHIO

1878 inclusive, occur in this month as in the last, and the records for the station at Marquette, show that a rainfall of over 4.00 inches has occurred only once during the period of eighteen years, and this occurred in 1879, amount 4.02 inches. The chart shows an average rainfall of 3.00 or more inches in the counties of Branch, Calhoun, Berrien, Hillsdale, Jackson, Lenawee, Monroe, and Washtenaw, while the remaining portion of the southern peninsula has an average of from two to three inches.

The rainfall in the years 1872, 1873, and 1877 were light over the state, and that of 1877 was the lightest on record, the average for the state being 0.21 inches, and the amount at Port Huron was but a trace, for the month.

The largest monthly rainfall which is recorded at nine of the selected stations, 8.09 inches, was recorded at Marshall, Calhoun county, in 1883, although the average for 1881 was larger throughout the state than for this year, the average being for 1881, for the state, 4.69 inches.

The rainfall for the month of February, as shown by the records is not of a steady average but deviates very much, one year may have a large amount of rainfall while the next will be light, and the data compiled from the records would not go far to prove any prediction of what would naturally be expected from the light of the past. February is subject to heavy local snowfalls, and then again to light ones, and these do not seem to follow in any order, but seem to be subject entirely to the local influences that then predominate.

It will be noticed that the records at Marshall, Calhoun county, which extend back to 1880, give an average of 4.05 inches. This large average is due probably to the shortness of the record, and that in 1881, 1883, and in 1887 rainfalls of five inches and over were recorded.

These are the only marked peculiarities which are noticed in the records as filed.

CORRESPONDENCE.

PUBLIC METEOROLOGICAL STATIONS.

To the Editors:—I desire to invite the attention of American meteorologists to the excellent method adopted in various countries of Europe, especially Germany, of popularizing meteorology by means of the barometer columns.

A barometer column is a small open pavilion, often quite ornamental, having in the center a square pier the upper part of which is used to display instruments, &c. On the north side, protected by a glass case, are a barometer, thermometer, and hygrometer, with explanations attached. On the other sides are posted bulletins, weather maps, and other meteorological information, and in many cases there is also a standard clock.

It has occurred to me that this plan might be advantageously adopted in our country; it is certainly a good way to interest the general public in meteorology. O. B. C.

Boston, January 16, 1890.

COINCIDENCE OF EXTREME WEATHER ABOUT THE NORTHERN HEMISPHERE.

To the Editors:—There is a noteworthy similarity betwixt weather conditions in the eastern and western hemispheres the past few months. There has been the same brevity of duration of cold waves and general mildness particularly in Russia. It has been assumed that the spread of the influenza is due to these extraordinary atmospheric conditions. Such correspondence of the weather is however by no means exceptional. It was apparent at the time of the floods culminating in the Johnstown disaster which were paralleled within three days by floods in China. At the time of the New York blizzard also the entire northern hemisphere was belted by a series of wind-storms of very exceptional severity. The storms of May, 1886, were likewise almost unique and burst forth coincidently on both sides of the Atlantic. In like manner from Dec. 31, 1854 to Jan. 3,

1855, the entire northern hemisphere was belted by a series of storms that have become historic on account of their severity and extent. Other years that will always be remembered are 1812, 1816, 1780 and 1740, because of the extraordinary cold that prevailed on both sides of the Atlantic. They have been variously designated as famine years, years without a summer, and the like. 1835 was another year of similar character, the cold being extreme in the United States and of long continuance. Details in regard to Europe are lacking at the present writing, but the year 1835 is remembered in China, because snow fell at Canton, a thing unheard of before or since, showing that cold waves were sweeping unusually far southward in that country as well as the United States. It is indeed surprising to what an extent exceptional weather conditions co-exist in the manner indicated.

M. A. VEEDER, M. D.

LYONS, N. Y., Jan. 9, 1890.

ANEMOMETER EXPERIMENTS.

TO THE EDITORS:—The *Quarterly Journal* of the Royal Meteorological Society for October, 1889, gives the results of recent wind pressure experiments made by Mr. Dines. In the discussion of the paper, as read before the Society, Mr. Whipple, referring to American anemometer experiments, remarks: "It was noteworthy that the apparatus used was almost an exact copy of that constructed by Mr. Dines." So many of these whirlers have been used and described many years since that originality of design except as regards very minor details is quite out of the question and somewhat ridiculous. In any case, however, the American machine can hardly be considered "almost an exact copy" of Mr. Dines's machine, as it has but one horizontal arm thirty-five feet long, while the English whirler is understood to have two such arms about twenty-nine feet long. Moreover, the American experiments were all made and the machine removed fully two months before the published description of Mr. Dines's machine appeared in the *Quarterly Journal* for October, 1888.

Did one desire to avail himself of any ingenious details that

Mr. Dines may have introduced in his whirler, the meagre description and the primitive and elementary sketch given in the *Quarterly Journal*, afford little or none of the desired information and leaves one quite at a loss as to important points that arise in a critical examination of the experimental results.

The statement that one peculiar feature of Mr. Dines's machine is that it "created no swirl of air," shows, in itself, either a very inaccurate idea of what constitutes an objectionable "mitwind," or, that very crude and untrustworthy methods have been depended upon to show its existence and measure its effects.

C. F. MARVIN.

WASHINGTON, D. C., December 30th, 1889.

POUDRÉ.

TO THE EDITORS.—Low temperature has prevailed here for the last ten days, the mercury remaining nearly or quite all the time below zero. The coldest registered was —32°, on the morning of the 21st inst.; but the mercury seldom failed to reach —20° on any of these nights and two or three times reached —30°. During the cold periods the air is comparatively still.

On the 22d a strong south wind raised the mercury to +10°, and on the night of the same day the air was full of crystals of ice, or frost, feeling like snow, but not falling like it, and so thick as partially to obscure the stars.

The reflection of the street lamps, and particularly the electric light, on these ice spiculæ produced long streamers of light, all tending toward the zenith of the observer; that produced by the electric light being so nearly identical with the aurora borealis in appearance as readily to be mistaken for it.

Frequent mirages occur in the morning, by which objects fifteen, twenty, and even forty miles away can be seen across the level prairie.

Parhelia are very common, and occasionally paraselenæ are visible, the latter on one occasion beautifully and prismatically colored.

LUDOVIC ESTES.

GRAND FORKS, Jan. 22, 1890. University of North Dakota.

CURRENT NOTES.

THE BATAVIA OBSERVATORY.—The published volumes for 1888 are the Magnetical and Meteorological Observations at Batavia (quarto, 203 pages, Volume IX of the series), and the octavo volume of Rainfall in the East Indian Archipelago (420 pages, Volume X of the series). The former volume has none of the appendices which in previous volumes have broached so many subjects of interest. In the rainfall volume daily observations are given for 102 stations on Java and Madœra, 42 on or near Sumatra, and 45 on other islands. This is an increase of several on last year.

THE SIGNAL SERVICE BIBLIOGRAPHY.—The second part of this bibliography has appeared. It is on the same plan, and about of the same size (475 pages) as the previous one on Temperature This part relates to Moisture, and we are very sorry to see that the Chief Signal officer announces that it is not practicable to issue other parts from his office. Corrections to the previous part were invited but none have been received, but the bibliographer (Mr. Fassig) has discovered a few which he has issued on supplementary sheets. I have tested both parts with some references, but have not found them in fault except in omissions, for dates before 1881,—since that date the bibliography is professedly incomplete. For instance, in this second part I find no reference to Lorenz von Liburnau's book on "Wald, Klima, und Wasser," (1878), nor to Löffelholz-Colberg's "Bedeutung und Wichtigkeit des Waldes," (1872). It might be expected too, that, notwithstanding the incompleteness since 1881, Ruskin's book on the "Storm-Cloud" would find mention, and also such an article as Woeikof's "Einfluss der Wälder" in the *Geogr. Mitth.* for 1885.

But the undertaking was a laborious and valuable one, and it has been well done.

AMERICAN METEOROLOGICAL JOURNAL.

AN ILLUSTRATED MONTHLY

DEVOTED TO SCIENTIFIC METEOROLOGY AND ALLIED BRANCHES OF STUDY.

THE AMERICAN METEOROLOGICAL JOURNAL CO., Publishers and Proprietors,
Ann Arbor, Michigan.

M. W. HARRINGTON,
Director of the Astronomical Observatory, Ann Arbor, Michigan,
A. LAWRENCE ROTCH,
Proprietor of the Blue Hill Meteorological Observatory, Massachusetts,
W. J. HERDMAN, PH. B., M. D.,
University of Michigan.
Editors.
KITTREDGE & MORAN, Managers.

PRICE,—IN THE UNITED STATES, - - - - $2.00 per year
" IN COUNTRIES OF THE POSTAL UNION, - - 2.25 " "

The editors solicit communications on all subjects having any bearing on Meteorology, or Climatology. Correspondence on events of current interest is invited, and accounts of local newspapers concerning them will be welcome. Notes on local climate will be published and the columns of the JOURNAL are freely open for worthy communications on all matters within its scope. The editors do not hold themselves responsible for any communications which may be signed or attributed to other authorship than their own.

Contributors will be furnished free with five copies of the issue in which their articles appear. Additional copies can be furnished them at the rate of 12 for $2.00. Reprints will be furnished, with cover and title, at the rate of $6.00 per hundred for anything less than one form (16 pages); $12.00 between one and two forms; and $6.00 for each additional form or fraction. The order for reprints must accompany the copy.

Communications relating to the contents of the JOURNAL may be sent to either editor. Subscriptions and all other letters relating to business matters, should be sent to the

AMERICAN METEOROLOGICAL JOURNAL CO.,
Ann Arbor, Mich.

JUST OUT!

SEARCHES IN ELECTRO-ALLOTROPIC PHYSIOLOGY

aining much scientific information and many valuable abstracts on Electro-Therapeutics. This handsome 115 pp. pamphlet will be mailed for only 24 cents in stamps ose who mention "THE AMERICAN METEOROLOGICAL JOURNAL." Address,

JEROME KIDDER M'F'G CO., 820 Broadway New York, N. Y.

Chicago, Milwaukee & St. Paul R'y.

Steam Heated and Electric Lighted Vestibuled Trains to St. Paul and Minneapolis.

Finest Dining Cars in the World.

Through Sleeping Cars to Denver.

The Route of the first "Golden Gate Special."

Excursion Tickets to Colorado.

Excursion Tickets to Calfornia.

Everything First-Class.

First-Class People patronize First-Class Lines.

Ticket Agents everywhere sell Tickets over the Chicago, Milwaukee & St. Paul Railway.

NORTHERN PACIFIC RAILROAD

LANDS FOR SALE.

The Northern Pacific Railroad Company has a large quantity of very productive and desirable **AGRICULTURAL AND GRAZING LANDS** for sale at LOW RATES and on EASY TERMS. These lands are located along the line in the States and Territories traversed by the Northern Pacific Railroad as follows:

In Minnesota,	- - - -	Upwards of 1,350,000 Acres
In North Dakota,	- - - - -	" 7,000,000 Acres
In Montana,	- - - -	" 19,000,000 Acres
In Northern Idaho,	- - - -	" 1,750,000 Acres
In Washington and Oregon,	- - -	" 12,000,000 Acres

AGGREGATING OVER 40,000,000 ACRES.

These lands are for sale at the **LOWEST PRICES** ever offered by any railroad company, ranging chiefly

FROM $1.25 TO $6.00 PER ACRE, AND ON 5 AND 10 YEARS' TIME,

For the best Wheat Lands, the best diversified Farming Lands, and the best Grazing Lands now open for settlement.

In addition to the millions of acres of low priced lands for sale by the Northern Pacific R. R. Co., on easy terms, there is an equal amount of Government lands lying in alternate sections with the railroad lands, open for entry, free to settlers, under the Homestead, Pre-emption and Tree Culture laws.

DO THIS!

WRITE FOR PUBLICATIONS RELATING TO MINNESOTA, NORTH DAKOTA, MONTANA, NORTHERN IDAHO, WASHINGTON AND OREGON

An attractive belt of country reaching from Lake Superior to the Pacific Ocean and Puget Sound, and noted for its rich natural resources.

The Northern Pacific Railroad Company mail free to all applicants the following **Illustrated Publications, containing valuable maps,** and describing Minnesota, North Dakota, Montana, Idaho, Washington, and Oregon. viz.:

A **SECTIONAL LAND MAP OF NORTH DAKOTA,** showing the Government lands open to settlers, and those taken up, and the railroad lands for sale, and those sold in the district covered by the map

A **SECTIONAL LAND MAP OF EASTERN WASHINGTON AND NORTHERN IDAHO,** showing the unoccupied and occupied Government lands, the sold and unsold railroad lands, with descriptive matter relating to this portion of the Northern Pacific country.

A **SECTIONAL LAND MAP OF WESTERN AND CENTRAL WASHINGTON,** showing the unoccupied and occupied Government lands, the sold and unsold railroad lands, in Central and Western Washington, including the Puget Sound section, with descriptive matter concerning the extensive timber regions, mineral districts, and the **agricultural and grazing lands.**

A **MONTANA MAP,** showing the Land Grant of the Northern Pacific R. R. Co., and the Government surveys in the district covered by the map, with descriptions of the country, its grazing ranges, mineral districts, forests, and agricultural sections.

ALSO SECTIONAL LAND MAPS OF DISTRICTS IN MINNESOTA.

When writing for publications, include the names and addresses of acquaintances, and publications will be sent to them also.

SUPERB TRAIN SERVICE.

The Northern Pacific passenger trains are equipped with Pullman palace sleeping cars, colonist sleeping cars, dining cars, and first-class coaches. The colonist sleeping cars are run on the daily fast through express trains, without extra charge for berths.

For full information relative to rates, tickets, sleeping and dining cars, and for copies of illustrated publications including the "Wonderland" and "Alice Folder," describing the summer resorts, Yellowstone National Park, California, Alaska, etc., with maps of the Park and line of road, apply to or address

CHAS. S. FEE, Gen'l Pass. and Ticket Ag't, St. Paul, Minn.

WRITE FOR PUBLICATIONS.

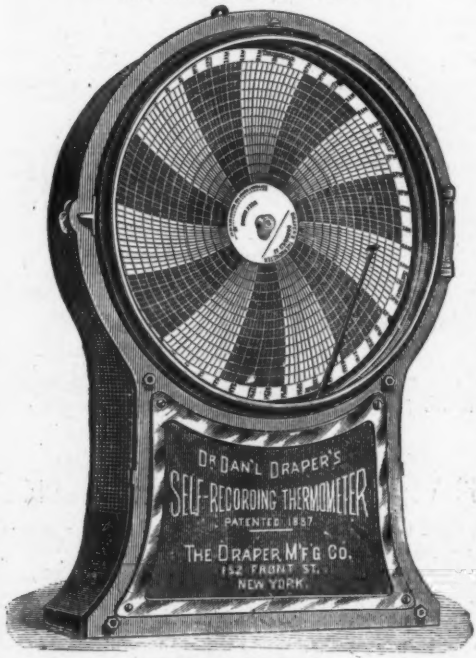
They are illustrated, and contain valuable maps and descriptive matter, and are MAILED FREE OF CHARGE to all applicants. For information relating to lands and the Northern Pacific country, address

P. B. GROAT, GENERAL EMIGRATION AGENT, OR **CHAS. B. LAMBORN,** LAND COMMISSIONER.

ST. PAUL, MINNESOTA.

DRAPER'S SELF-RECORDING THERMOMETER.

DESCRIPTION OF THE INSTRUMENT AND DIRECTIONS FOR ITS USE.



SIZE 14 BY 20 INCHES.

Protected by Letters Patent in the United States, Canada, Great Britain, France, Germany, Austria, Hungary and Belgium.

STANDARDIZED AND WARRANTED.

MANUFACTURED BY THE
DRAPER MANUFACTURING COMPANY,
152 FRONT STREET, NEW YORK CITY.

This thermometer gives a permanent and continuous record in ink of the temperature. The chart indicating hours of the day and days of the week, gives the degrees of temperature from 20° below zero to 110° above. All instruments are accurately adjusted and warranted. The record is easily read and absolutely correct. Sold by the leading instrument dealers and opticians throughout the United States and Canada, and by

The DRAPER
MANUFACTURING CO.,

Owners of the United States and foreign patents, 152 Front Street, New York.

COLORADO COLLEGE,

COLORADO SPRINGS, COLORADO.

THE CLASSICAL, LITERARY AND SCIENTIFIC DEPARTMENTS are now strongly equipped.
Special Winter Courses are given in Assaying and Determinative Mineralogy.
Students unable to continue their work in the East on account of Pulmonary diseases or Malaria, in this climate can pursue their studies uninterruptedly, and often regain their health at the same time.
For further information Address President SLOCUM.

ROSE POLYTECHNIC INSTITUTE, TERRE HAUTE, IND.

A SCHOOL OF ENGINEERING.

Well endowed, well equipped departments of Mechanical and Civil Engineering. Electricity Chemistry, Drawing. Extensive shops and Laboratories. Expenses low. For catalogue address T. C. Mendenhall, Pres.

EXCHANGE OF BOOKS.

Any one who has **Books of Travel**, or **Mathematics**, or odd, early volumes of **Harpers'**, **Scribner's**, or **St. Nicholas** which they wish to exchange for **Novels** or books on **Natural History** can perhaps effect the exchange by addressing **Lock-box 3034, Ann Arbor, Mich.**

STANDARD THERMOMETER.

LEGIBLE.

5 inch Dial.

$2.50.

ACCURATE.

8 inch Dial.

$2.50.

(Metallic.)

Special Thermometers for Meteorologists with or without Telemeter attachments.

AGENTS:

THE FAIRBANKS SCALE HOUSES

In the principal cities of the United States.

COMPTOMETER

SPECIALLY ADAPTED TO ALL

METEOROLOGICAL COMPUTATIONS.

Addition

Subtraction

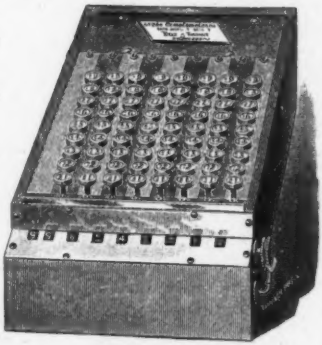
Multiplication

Division

Square Root

Cube Root

Common Fractions



Operated Entirely by Keys.

Saves 40 per cent of time.

Entire Relief from Mental Strain.

Adapted to all Scientific and Commercial Computations.

ALL Arithmetical Calculations can be solved Rapidly and Accurately by its use. . . . . Send for Circular.

FELT & TARRANT MFG. CO.,

52-56 ILLINOIS STREET, - - CHICAGO, ILL.